

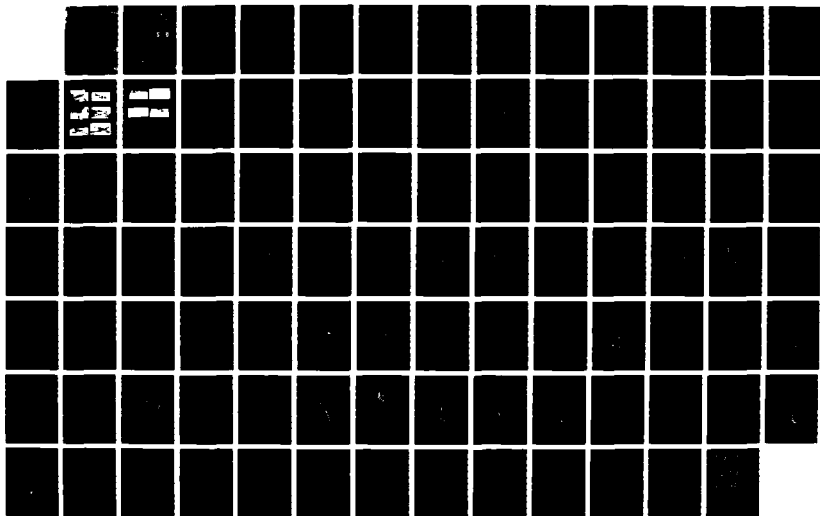
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CURRENT FIRE SAFETY DESIGN ASPECTS OF COMMUTER AIRCRAFT 1/1  
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FAA Technical Center  
Atlantic City International Airport  
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# Current Fire Safety Design Aspects of Commuter Aircraft

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March 1988

Final Report

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<p>16. Abstract</p> <p>This study describes Fire Safety systems, cabin design and materials in cabin areas of ten common commuter aircraft. The aircraft were selected based upon a balance of current population and aircraft most commonly delivered. These aircraft represent 880 of 1100 commuter aircraft and probably will be the majority of the commuter fleet in the future.</p> <p>The trend in these commuter aircraft is increasing sophistication in application of materials similar to those in large commercial aircraft. Among the ten aircraft two are older, piston powered aircraft, simple in design and materials applications. Of the other larger eight aircraft, two are no longer delivered. Four newer and larger designs feature large, separate baggage compartments. Only two aircraft have overhead storage bins.</p> <p>One aircraft has a large interior with standing headroom. The others are much more compact, with interior storage limited to bins at the entry point. Thermoplastics and composite materials are used in the newer aircraft. Each aircraft originally was equipped with polyurethane cushions; currently, operators and manufacturers are protecting cushions with fire-blocking materials.</p> <p>Piston powered aircraft use gasoline cabin heaters and ram cooling airflow. The other eight aircraft are turboprop aircraft using engine bleed air for cabin heating and cooling. Six aircraft are unpressurized and four are pressurized. One new design has an optional oxygen system using oxygen generators; the other aircraft use cylinder stored oxygen.</p>			
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## EXECUTIVE SUMMARY

This study describes fire safety systems and airframe design as well as applications of construction materials in cabin areas of ten common commuter class aircraft. The ten commuter aircraft have been selected to represent those aircraft most common in the commuter fleet. The aircraft in this study represent the majority of the current regional airline fleet of aircraft carrying thirty or fewer passenger, and, due to their numbers in service (880 out of 1100 commuter class aircraft), will remain representative of the population for several more years. The trend in the design of commuter airliners, as seen in this study, is that of increasing sophistication in application of materials similar to those found in large commercial aircraft. With the exception of two aircraft, the commuter aircraft are small and offer relatively high performance.

The aircraft in this study illustrate trends in the commuter aircraft industry. The only two piston powered aircraft originated as general aviation aircraft designs some years ago. They are relatively small and simple in both design and materials applications. Of the other and larger eight aircraft, two are at the end of their delivery periods. These are a derivative of aircraft which were adapted to commuter service. One other aircraft, while a relatively new design, is not being delivered currently due to market desire for larger aircraft.

Of the eight larger aircraft, application of modern, composite materials is a major characteristic of the aircraft. Four of the newer and larger designs feature large, rear located, separate baggage compartments, leaving the cabin for seating. Only in two are overhead storage bins found.

Of the ten aircraft, one has a large interior that allows standing headroom in its large interior volume. The other aircraft are much more compact, with interior storage limited to bins at the entry end of the aircraft. Weight saving seems to be key to design success, possibly affecting the selection of various new thermoplastics and composite materials for the interiors. Each aircraft was originally delivered with polyurethane cushions; currently operators and manufacturers are involved in covering these cushions with fire blocking materials to upgrade fire safety.

The two piston powered aircraft use gasoline fired heaters to provide cabin heat and ram air flow to provide outside air for cabin and cockpit cooling; these heaters are not equipped with fire detection or extinguishing systems. The remainder of the aircraft are turbine powered, turboprop aircraft that use engine bleed air for heating and cooling of the interior air. Six of the ten aircraft are unpressurized aircraft while four are of pressurized design. The unpressurized aircraft have oxygen available for the pilots and passengers, often in portable storage form. The pressurized aircraft feature cabin oxygen for the passengers. Each of these aircraft reflect their operating environment of short, low altitude flight legs, not requiring design of oxygen systems characteristic of large commercial aircraft. In some of the aircraft, the fixed oxygen system is an option picked only by operators faced with the need for sustained high altitude operations, such as in mountainous areas. In these aircraft, oxygen is meant for emergency use of the crew and individual passengers with a temporary need.

## INTRODUCTION

### PURPOSE.

The purpose of this study was to achieve an understanding of the basic fire safety related design and materials application characteristics of aircraft commonly found in the U.S. commuter aircraft fleet. The goals of the study were to:

- Survey the makeup of the commuter fleet to identify ten aircraft that are both common and typical of the commuter aircraft in use.
- For those ten aircraft, identify the materials used in the cabins of the aircraft.
- For those ten aircraft, identify and describe the compartmentation and materials used in partitioning the aircraft.
- For those ten aircraft, identify and describe fire detection and suppression, oxygen, ventilation systems and hand held fire extinguishers.

### BACKGROUND.

Since enactment of the Airline Deregulation Act of 1978 there have been major changes in the character of U.S. commercial aviation. Scheduled air carriers have concentrated their resources to meet new competition by forming "hub and spoke" route systems. With major airlines concentrating on larger cities, small towns and cities suffered a loss of air service. In an attempt to meet this need, both existing and new commuter airlines entered the vacated markets and expanded service to other communities not previously served.

In this way a formerly small and ill defined part of the air transportation system changed into a major aviation activity --- commuter or regional airlines. Starting with small aircraft that were originally general aviation in origin and with older aircraft at the low end of the transport aircraft spectrum, the commuter carriers struggled through several years of economic hardship to establish visibility and credibility in the eyes of the traveling public. One of the problems faced by commuter carriers was the lack of modern, economic aircraft to meet the rapidly expanding service needs. Then, in the early 1980s, aircraft and engine manufacturers began to market new aircraft that were modern in design, powered by turboprop engines and carrying up to thirty passengers. Those aircraft, many manufactured overseas, are now becoming a common sight at U.S. airports. The newly created U.S. commuter fleet is now in service and, due to its rapid growth focused in the 1980s, will retain its basic characteristics for many years to come.

Federal Aviation Administration (FAA) aircraft fire safety programs have been primarily devoted to transport category aircraft. A large body of knowledge and experience had been amassed on these aircraft. Today, with the new commuter aircraft in service, no comparable body of information exists for those new commuter aircraft. For this reason, the FAA's Technical Center's (FAATC) Fire Safety Branch initiated this study to document the fire safety design characteristics of the commuter fleet to establish what sort of

research might be necessary in the future and how much of the existing data on aircraft construction and materials carries over to the new commuter aircraft fleet. Since these aircraft have only come into use in the last few years, there is no body of accident experience that is pertinent. Instead the opportunity existed to review the new fleet's characteristics and establish an information base to which future experience could be compared.

## THE POPULATION OF COMMUTER AIRCRAFT

### PURPOSE.

The first objective of the current Fire Safety Design Aspects of Commuter Aircraft was to develop a list of aircraft for which fire safety design details would be determined. For this stage of the project, commuter class aircraft with passenger capacity of thirty or fewer passengers were reviewed and ten were selected for further study.

### APPROACH.

Two separate approaches were used to obtain the final list of commuter aircraft. The first approach was to identify the ten most populous commuter aircraft used in the U.S. while the second approach was to identify the six commuter aircraft being sold or delivered at the highest rates during the most recent two years. From these two lists, a combined list balancing past production against future deliveries was developed.

### POPULATION RESEARCH.

According to the FAA's Census of U.S. Civil Aircraft for 1984, the ten most common commuter aircraft were the following.

TABLE 1. THE TEN MOST COMMON COMMUTER AIRCRAFT BASED  
ON FAA CENSUS OF CIVIL AIRCRAFT - 1984.

Type	Number
Piper Navajo PA-31	107
Cessna 402	99
Fairchild Metro II SA-226	97
deHavilland Twin Otter DHC-6	97
Beech 99	79
Fairchild Metro III SA-227	70
Embraer Bandeirante EMB-110	68
Pilatus Islander BN-2	27
Casa 212	27
Beech 1900	17

A second list of ten was developed from two other sources, the Regional Airline Association's (RAA) 1986 Annual Report of the Regional/Commuter Airline Industry and the FAA's Aircraft Utilization & Propulsion Reliability Report for May and June, 1986. In comparing these two sources, it was noted that the totals for the different aircraft types varied, yet the top ten commuter aircraft were nearly the same in each source. Balancing the varying

totals on the ten most common aircraft in these sources, the following fleet total was developed.

TABLE 2. THE TEN MOST COMMON COMMUTER AIRCRAFT BASED ON REGIONAL AIRLINE ASSOCIATION AND FAA DATA - 1986.

Type	Number
Cessna 402	190
Piper Navajo PA-31	109
Beech 99	106
deHavilland Twin Otter DHC-6	106
Fairchild Metro II SA-226	103
Fairchild Metro III SA-227	97
Embraer Bandeirante EMB-110	86
British Aerospace BAe Jetstream 3100	83
Beech 1900	47
Shorts 330 SD 3-30	41

The World Aviation Directory tabulation of "Business/Personal Aircraft Unit Shipments" for calendar years 1984, 1985 and for the period January-October, 1986 was used to identify the commuter aircraft being sold or delivered at the highest rate during the most recent two years.

TABLE 3. WORLD AVIATION DIRECTORY TOTALS OF COMMUTER AIRCRAFT DELIVERIES FOR 1984, 1985 AND JANUARY-OCTOBER 1986.

Type	1984 Total	1985 Total	1986 Total
BAe Jetstream 3100	22	34	36
Beech 1900	29	21	13
Cessna 402	11	14	1
deHavilland DHC-6	14	18	2
Embraer EMB-110	9	8	5
Embraer EMB-120	-	6	10
Fairchild SA-227	23	20	23
Pilatus BN-2	5	2	6

Eight, rather than the required six aircraft, were reported since these eight were the only commuter aircraft being delivered in significant numbers in the 1985-1986 period.

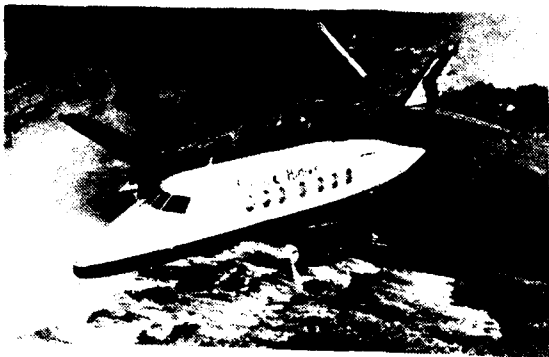
#### POPULATION DEFINITION.

The lists shown in tables 2 and 3 were provided for consideration and compilation into a composite list reflecting both existing commuter aircraft and those likely to be most common in the future due to delivery trends. Such a list was determined after consultation with FAA Central Region representatives responsible for commuter aircraft certification. The final list of ten aircraft for further study was selected from the candidate aircraft and is as follows:

TABLE 4. ALPHABETICAL LIST OF THE TEN COMMUTER AIRCRAFT  
SELECTED FOR INCLUSION IN THE FAA COMMUTER AIRCRAFT FIRE STUDY.

British Aerospace BAe Jetstream 3100  
Beech 99 (BE-99)  
Beech 1900 (BE-1900)  
Cessna 402 (CE-402)  
deHavilland Twin Otter (DHC-6)  
Embraer Bandeirante (EMB-110)  
Embraer Brasilia (EMB-120)  
Fairchild Metro III (SA-227)  
Piper Navajo (PA-31)  
Shorts 330 (SD 3-30)

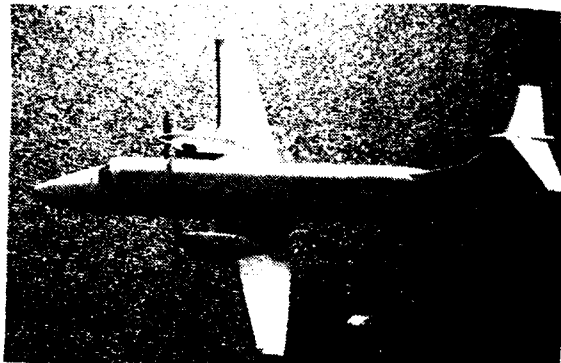
These ten aircraft, in the summer of 1986 represented an approximate total of 880 of the nearly 1100 commuter aircraft counted by the FAA as being in the U.S. commuter aircraft fleet. From this it can be seen that the ten aircraft are representative of the present fleet and likely will remain so for some time to come.



BAe JETSTREAM 3100  
19 PASSENGERS



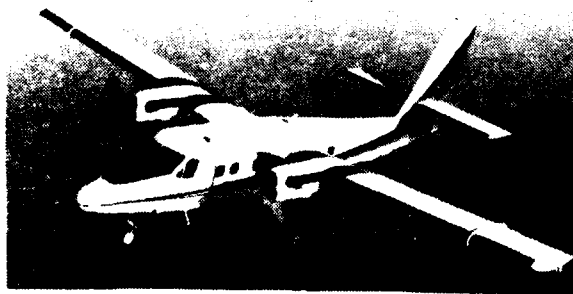
BEECH 99  
15 PASSENGERS



BEECH 1900  
15 PASSENGERS



CESSNA 402  
8 PASSENGERS



TWIN OTTER SERIES 300  
20 PASSENGERS



EMBRAER BANDEIRANTE  
19 PASSENGERS

FIGURE 1. ILLUSTRATIONS OF THE TEN SELECTED COMMUTER AIRCRAFT (1 of 2 pages)





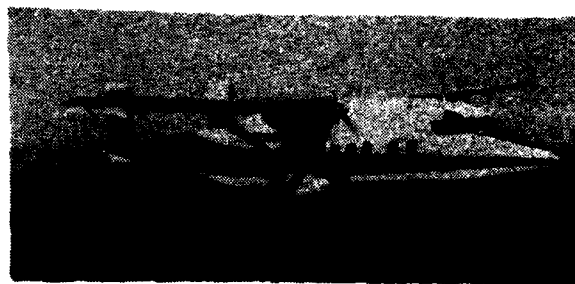
EMBRAER BRASILIA  
30 PASSENGERS



FAIRCHILD METRO III  
19 PASSENGERS



PIPER NAVAJO  
9 PASSENGERS



SHORTS 330  
30 PASSENGERS

FIGURE 1. ILLUSTRATIONS OF THE TEN SELECTED COMMUTER AIRCRAFT (2 OF 2 PAGES)

## COMMUTER AIRCRAFT MATERIALS AND SYSTEMS RESEARCH

### PURPOSE.

The intent of the Current Fire Safety Design Aspects of Commuter Aircraft was to document the fire safety provisions and design elements of the ten selected aircraft. This documentation focused on three general areas of aircraft design and construction: cabin materials, aircraft compartmentation and fire related systems. For cabin materials, the study covered: cabin and baggage area liners, floor coverings, major transparencies, seats, insulation, cabin area fuselage skin thickness, and flight deck and cabin area wire insulation. For aircraft compartmentation the intent was to portray baggage area location and accessibility, lavatory location and materials of construction, galley location and materials of construction, cabin firewalls and materials of construction, flight deck firewalls and materials of construction, partitions and their composition, and stowage compartments and their composition. For fire related systems this study describes fire detection and suppression systems, on-board hand held fire extinguishers, oxygen systems, and ventilation systems. Both text and illustrations are used in explaining these systems' details.

### METHODOLOGY.

For each aircraft a two-fold approach was taken in obtaining the necessary information. Each manufacturer was contacted regarding the information requirements. At the same time, operators of the ten selected aircraft were contacted to obtain similar information. Based upon conversations with manufacturers and operators, representative aircraft configurations were selected. This was due to the variety of configuration options that were available in several of the aircraft. The configuration selected for the study was felt to be the most likely to be encountered or the most common in the fleet, for that aircraft. As an example, though most of the aircraft could be equipped with a galley, galleys were not generally an option selected by operators faced with the need to maximize revenue producing load over often short flight distances and times.

### ORGANIZATION.

The data developed in this investigation are organized on a topic basis rather than a model basis. Much of the information is presented through illustrations. Aircraft compartmentation is described in illustrated format in figures 2 through 11. Amplification of some details of compartmentation is offered by text descriptions.

Materials applications, except for fuselage skin thickness, are described in text form with each aircraft being summarized under separate material application, e.g., cabin and baggage area liners are described for each of the ten aircraft, followed by descriptions of floor coverings for each of the ten aircraft. Cabin area fuselage thickness for each of the ten aircraft is described in pictorial form in figures 12 through 21.

Aircraft fire related systems are described using both illustrations and text. Figures 22 through 43 illustrate layout of fire detection and suppression systems, oxygen systems and ventilation systems. This information is supplemented by text descriptions of design specifications and other details.

## COMPARTMENTATION

### BAGGAGE AREAS.

For purposes of describing the fireworthiness capabilities of cargo or baggage compartments, transport category aircraft cargo/baggage compartments are described by five classes of fireworthiness. Each is typified by differing characteristics of accessibility, ventilation, fire or smoke detection, fire extinguishing, and volume. These classifications are listed in Federal Aviation Regulations Part 25.857 - Cargo Compartment Classification. Though several of the aircraft surveyed for this report were not designed according to the standards of Part 25, which applies to transport category aircraft rather than commuter aircraft, several of the manufacturers have described the fire worthiness characteristics of their aircraft's baggage compartments in terms of the Part 25 classification. The five classes of baggage compartment are summarized, below:

Class A - A compartment in which the presence of fire would be easily discovered while a crewmember is at his or her station and the compartment is easily accessible, in flight.

Class B - A compartment in which there is sufficient access, in flight, to enable a crewmember to effectively reach the entire contents of the compartment with a hand fire extinguisher. Further, when the crewmember is accessing the compartment, no hazardous quantity of smoke, flames, or fire extinguishing agent will enter any compartment occupied by crew or passengers. For this Class of compartment there must be a separate, approved smoke or fire detector at the pilot's or flight engineer's station.

Class C - A compartment not meeting the requirements of either Class A or B, but which has a separate, approved fire or smoke detector at the pilot's or flight engineer's station. Class C compartments will have an approved, built in fire extinguishing system controlled at the pilot's or flight engineer's station. Like the Class B compartment, the Class C compartment must have means to prevent hazardous quantities of smoke, flames, or fire extinguishing agent from entering any compartment occupied by crew or passengers. In addition to these requirements, the Class C compartment will have means to control ventilation and drafts within the compartment so that the fire extinguishing agent can control any fire that may start within the compartment.

Class D - These are compartments in which a fire occurring in the compartment will be completely confined without endangering the safety of the airplane or the occupants. For Class D compartments there will be means of preventing hazardous quantities of smoke, flames, or fire extinguishing agent from entering any compartment occupied by crew or passengers, and both ventilation and drafts will be controlled

so any fire within the compartment will not progress beyond same limits. For Class D compartments consideration will be given to the effect of heat within the compartment on adjacent critical parts of the airplane. For compartments of 500 cubic feet or less volume, an airflow of 1500 cubic feet per hour is acceptable. The volume of a Class D compartment will not exceed 1,000 cubic feet.

Class E - These compartments are used only for the carriage of cargo and must have a separate, approved smoke or fire detection system at the pilot's or flight engineer's station. For these compartments there will be means to shut off ventilation airflow to or within the compartment, and the controls for these means will be accessible to the flight crew in the crew compartment. There will be means to prevent hazardous quantities of smoke, flames, or fire extinguishing agent from entering the flight crew compartment; and required crew emergency exits will be accessible under any cargo loading condition.

Of the ten aircraft, eight used the fuselage area for baggage storage, usually in baggage compartments behind the cabin, and often in smaller compartments forward of the cockpit. In the Cessna 402, Jetstream 3100, Fairchild Metro III, Beech 99, and Piper Navajo, the fuselage baggage area is at the rear of the passenger cabin and is open to the cabin area. Only the Beech 99 series of aircraft featured use of an external belly pod for additional baggage. In the two smallest aircraft, the Cessna 402 and the Piper Navajo, baggage stowage is also possible in enclosed lockers at the top, rear of each of the engine nacelles. This nacelle location is a reflection of the origin of those two aircraft as general aviation aircraft. Figures 2 through 11 illustrate the location of the baggage areas as part of aircraft compartmentation.

TABLE 5. COMMUTER AIRCRAFT BAGGAGE AREAS

<u>Aircraft Type</u>	<u>Descriptions</u>
BAe Jetstream 3100	Open bin storage at the rear end of the cabin area. (96.7 cubic feet) open and accessible from inside the cabin.
Beech 99	Baggage areas forward of the cockpit (43.9 cubic feet) and behind the cabin (17.1 cubic feet), with the nose baggage not accessible in flight. Rear baggage compartment separated from cabin by webbing. Some aircraft equipped with a fiberglass belly pod (59.4 cubic feet) accessible only from outside.
Beech 1900	Baggage areas forward of the cockpit (13 cubic feet) and behind the cabin (154 cubic feet), neither accessible in flight. Additional baggage in a storage bin at the forward right of the cabin (15 cubic feet) opposite the entry door.

Cessna 402	Baggage areas forward of the cockpit (26 cubic feet), in the top rear section of each engine nacelle (8.9 cubic feet each), and behind the cabin (31.7 cubic feet). The nose and the nacelle baggage compartments are not accessible in flight. The rear baggage compartment is an open bin aft of the entry doorway in the rear of the cabin.
deHavilland Twin Otter	Baggage areas forward of the cockpit (38 cubic feet) and behind the cabin (88 cubic feet). The forward area (Class D) is not accessible in flight, while the rear baggage compartment (Class B) can be accessed through a hatch at the top center of the aft bulkhead of the passenger cabin.
Embraer Bandeirante	Single baggage bin (113 cubic feet) at the rear of the cabin, separated from the cabin by a folding vinyl divider.
Embraer Brasilia	Single Class D baggage compartment (226 cubic feet) behind the rear cabin partition and not accessible in flight.
Fairchild Metro III	Baggage areas forward of the cockpit (45 cubic feet) and behind the rear cabin bulkhead (136 cubic feet), neither accessible in flight. Open baggage bin at the right front of the passenger cabin.
Piper Navajo	Baggage areas forward of the cockpit (14 cubic feet) and in the top rear of each engine nacelle (13.25 cubic feet each), neither accessible in flight. Open baggage area at the rear of the cabin accessible in flight (22 cubic feet).
Shorts 330	Baggage areas forward of the cockpit (45 cubic feet) and behind the cabin (170 cubic feet), neither accessible in flight.

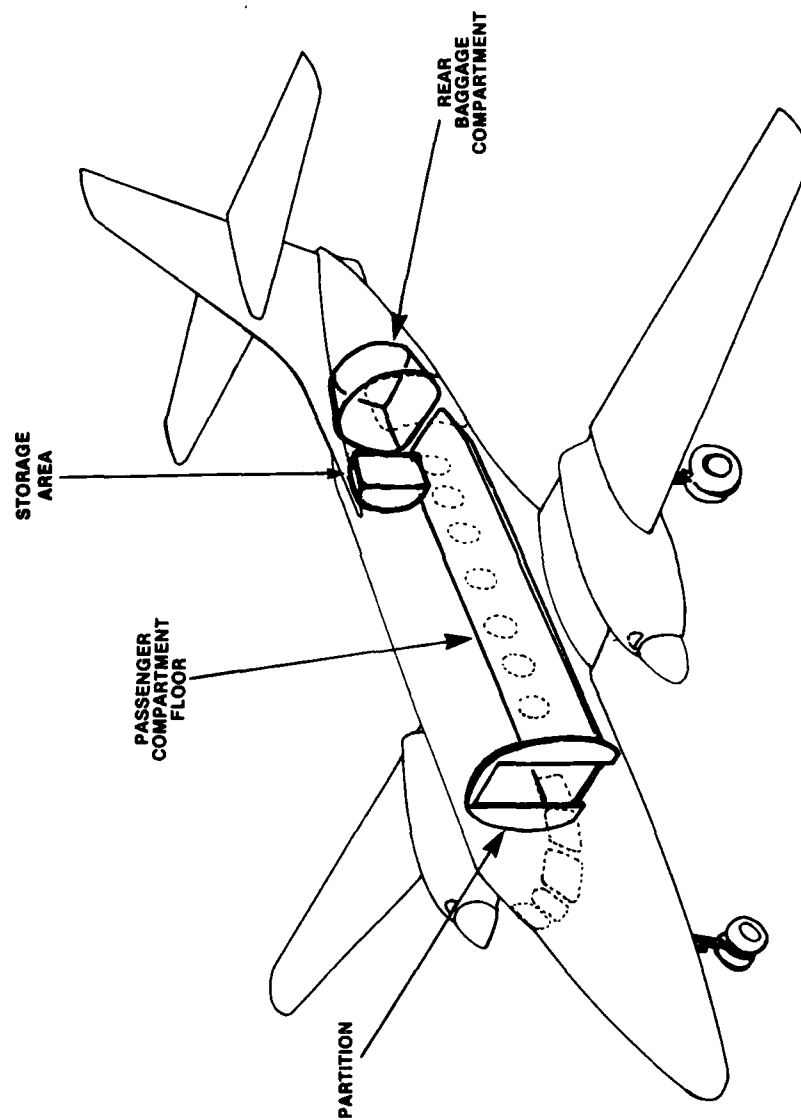
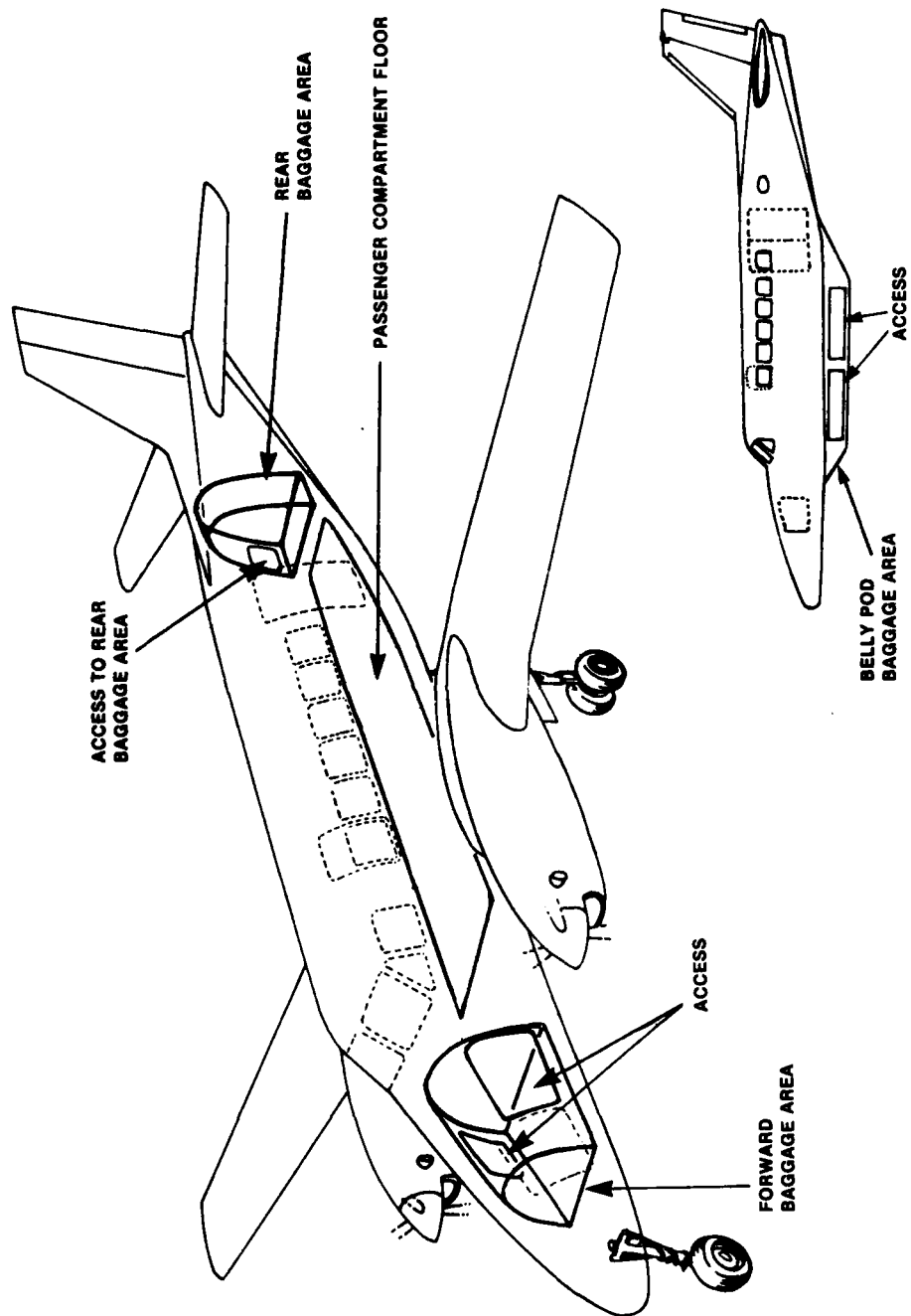
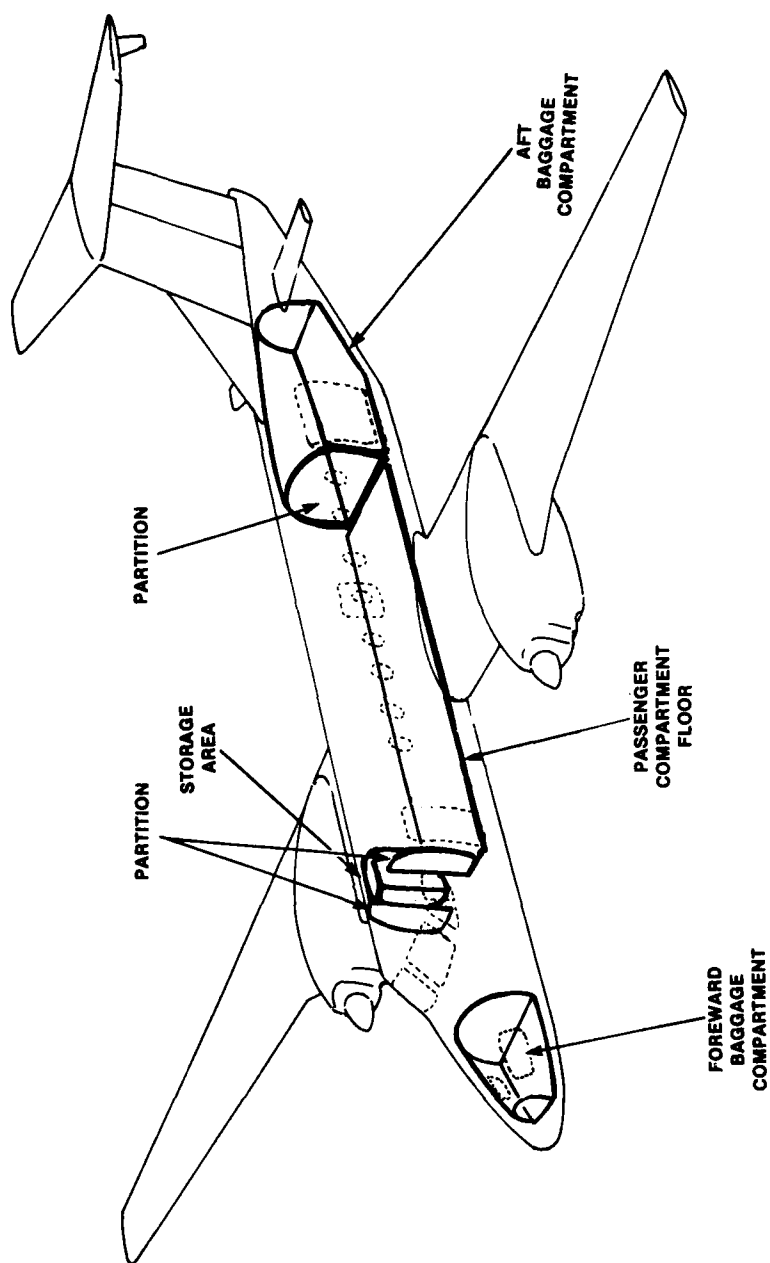


FIGURE 2. BAE JETSTREAM 3100 COMPARTMENTATION



**FIGURE 3. BEECH 99 AIRLINER COMPARTMENTATION**



**FIGURE 4. BEECH 1900 AIRLINER COMPARTMENTATION**



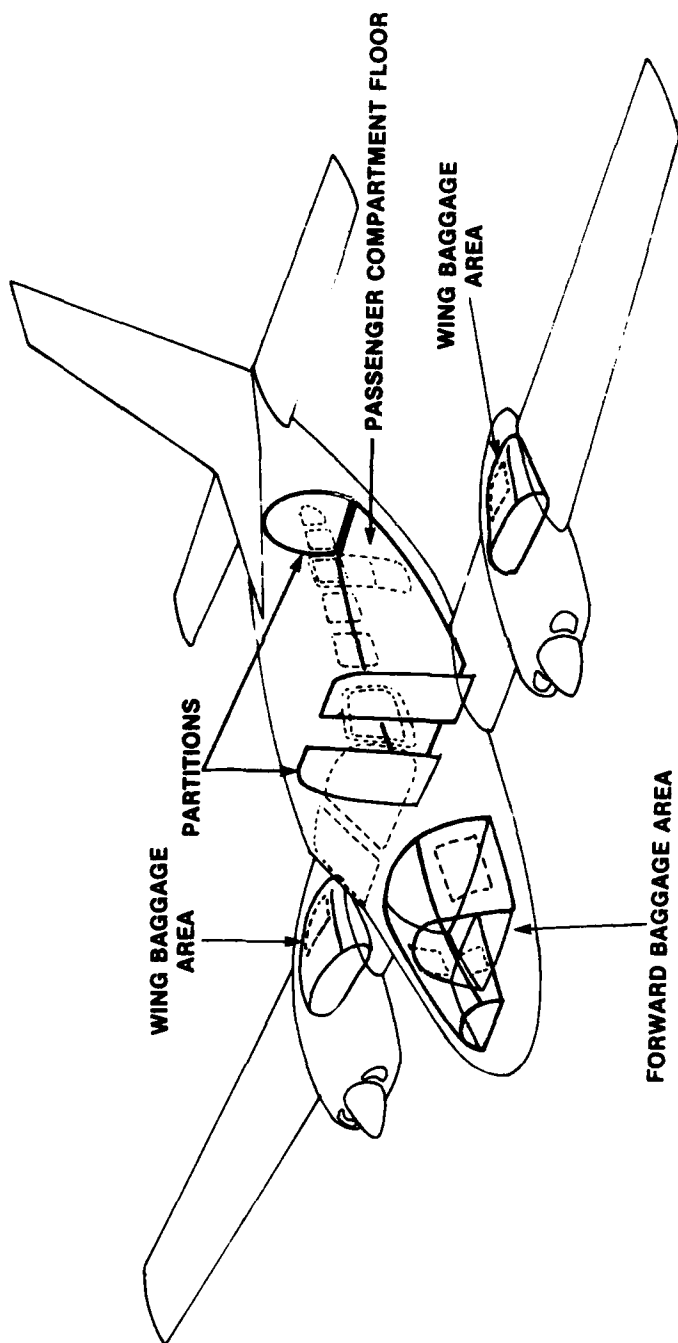
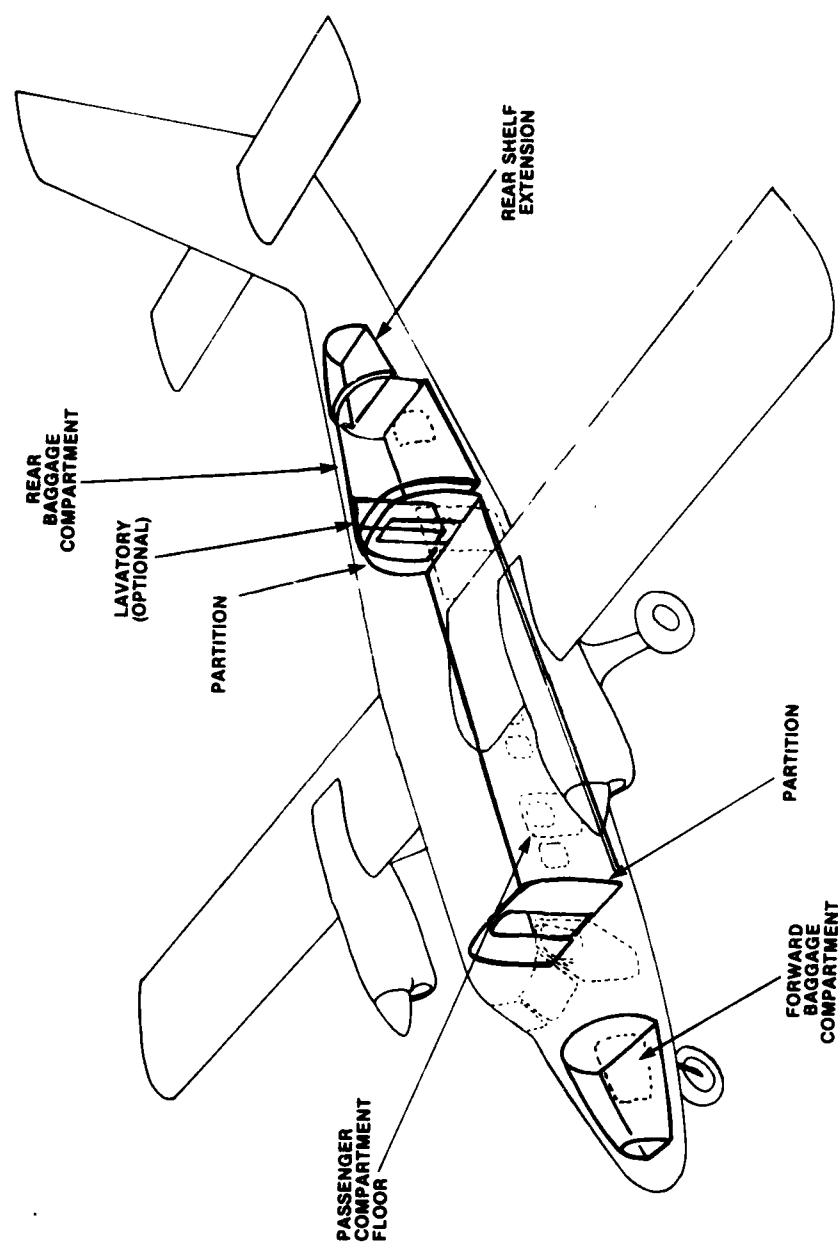


FIGURE 5. CESSNA 402 COMPARTMENTATION



**FIGURE 6. TWIN OTTER SERIES 300  
COMPARTMENTATION**

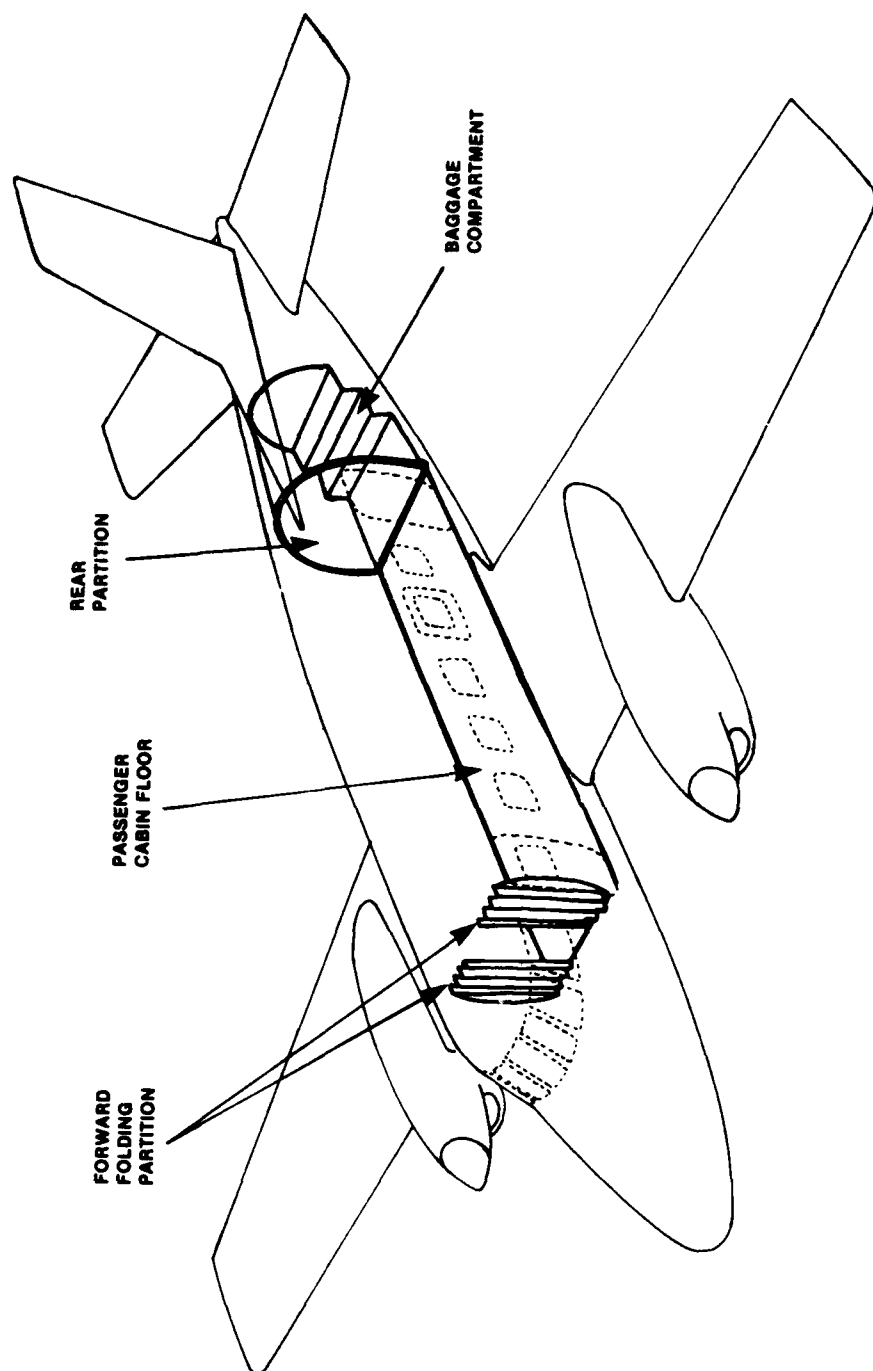
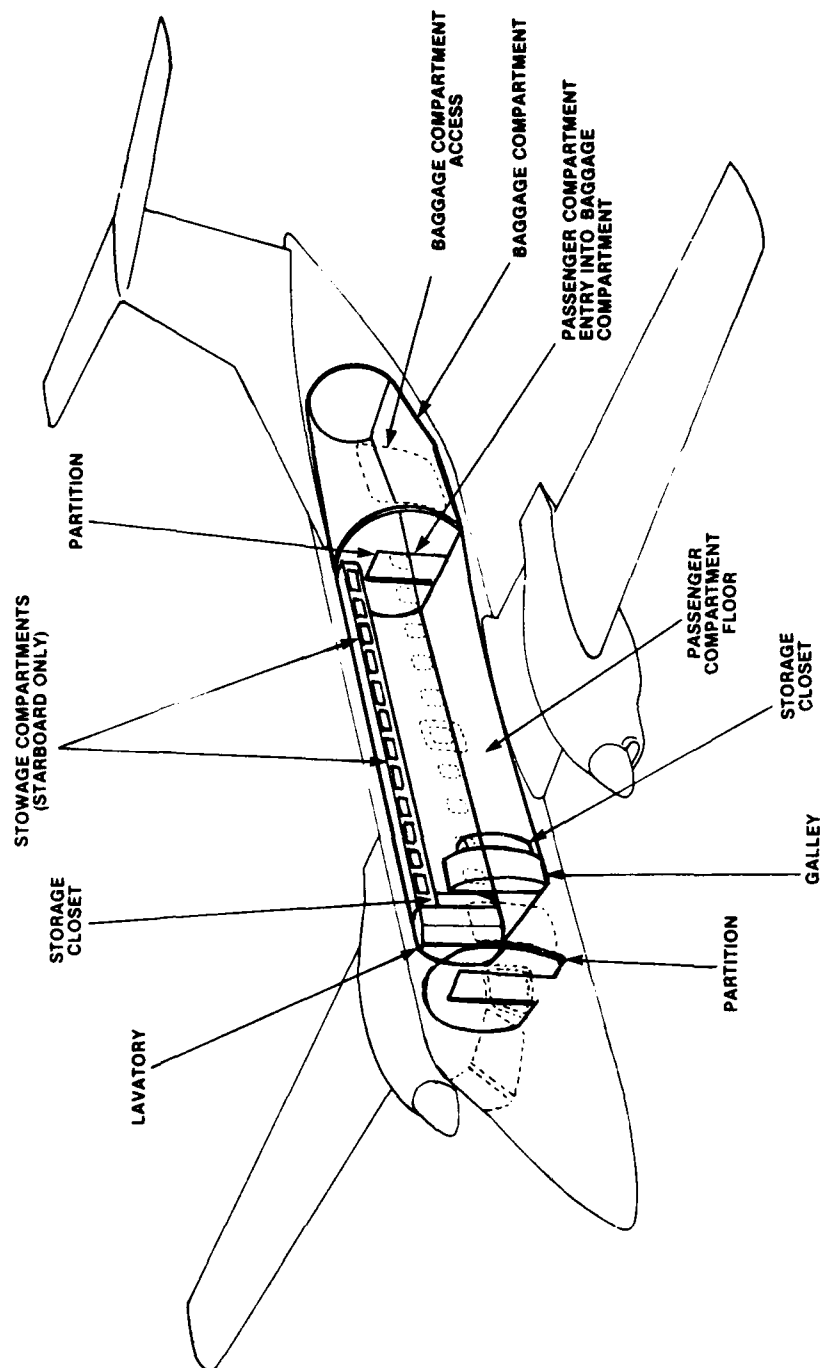


FIGURE 7. EMBRAER BANDEIRANTE COMPARTMENTATION



**FIGURE 8. EMBRAER BRASILIA COMPARTMENTATION**

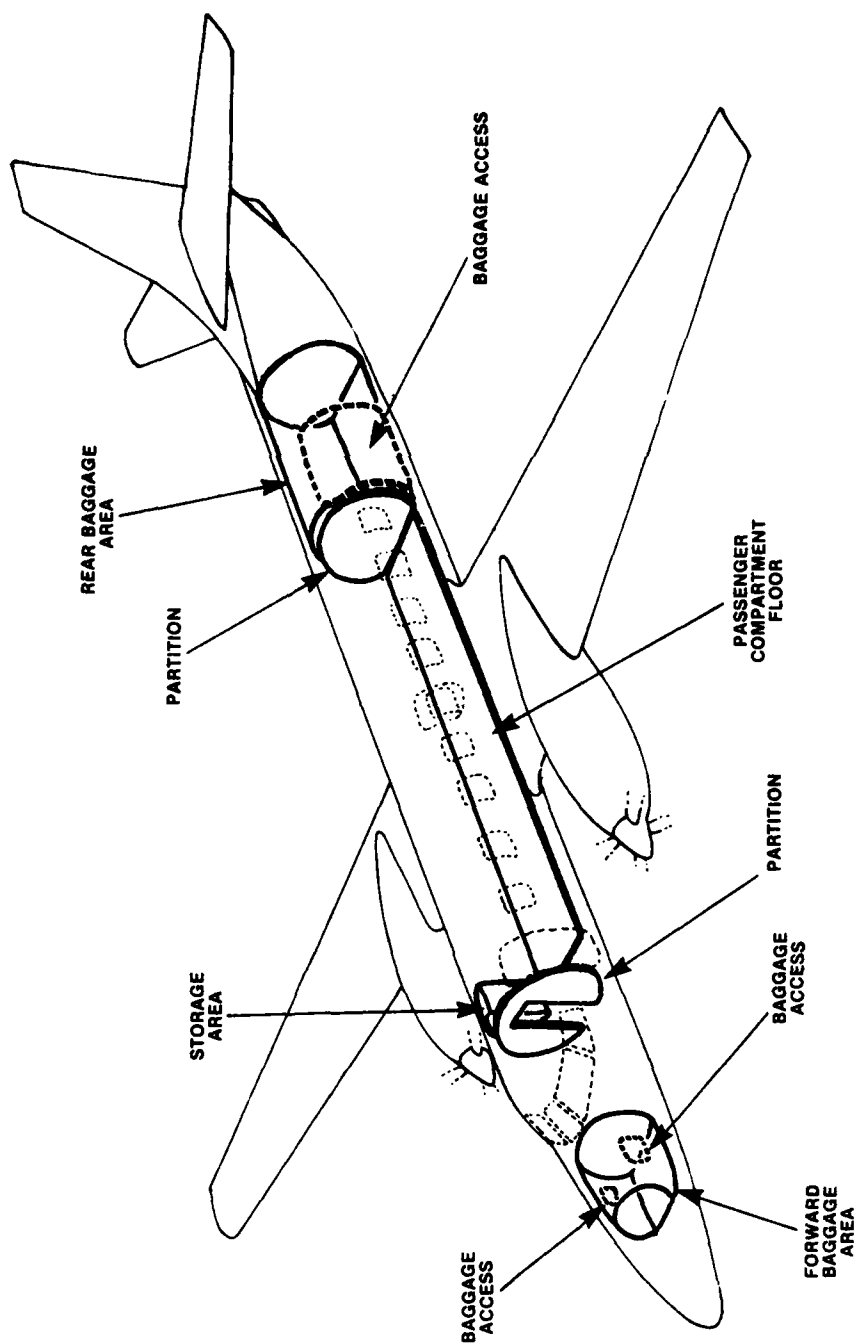


FIGURE 9. FAIRCHILD METRO III COMPARTMENTATION

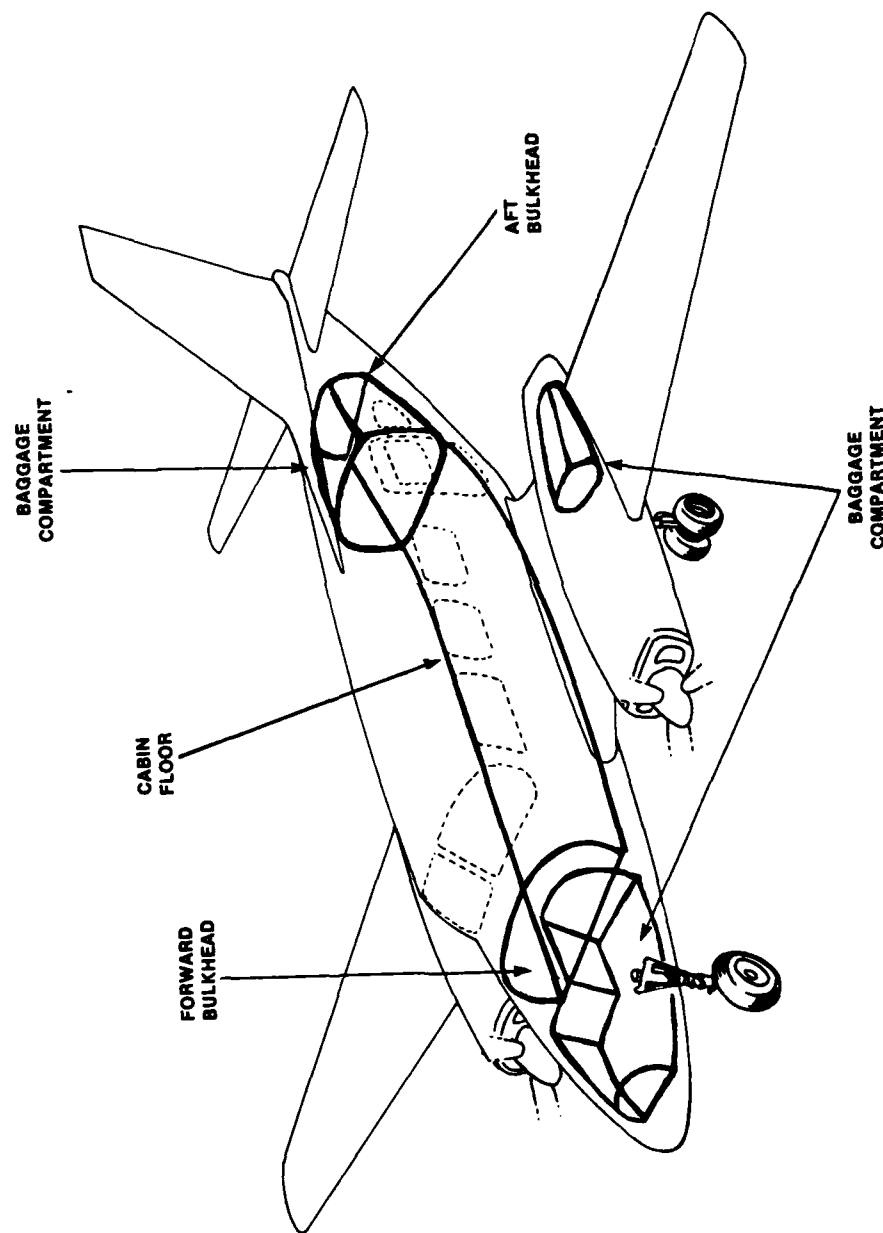


FIGURE 10. PIPER NAVAJO COMPARTMENTATION

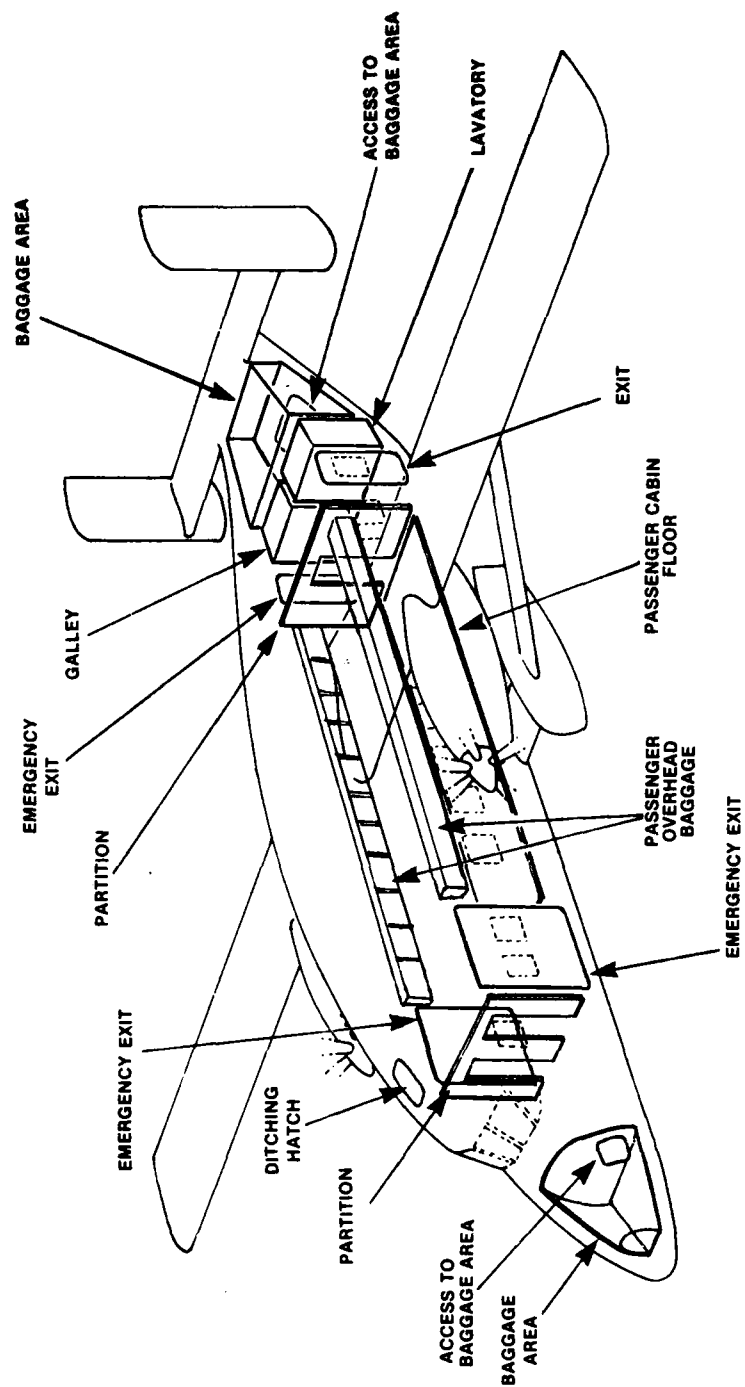


FIGURE 11. SHORTS 3-30 COMPARTMENTATION

### STOWAGE COMPARTMENTS.

Due to the size of most of the ten aircraft, stowage compartments are not common. In the larger aircraft, the Brasilia and Shorts 330, overhead bins are found in the cabin. In the Jetstream 3100 and the Fairchild Metro III, there are bin areas at one end of the cabin near the entry doorway.

TABLE 6. COMMUTER AIRCRAFT STOWAGE COMPARTMENTS

<u>Aircraft Type</u>	<u>Descriptions</u>
BAe Jetstream 3100	Stowage compartments at the right rear of the cabin opposite the entry doorway.
Beech 99	None.
Beech 1900	None.
Cessna 402	None.
deHavilland Twin Otter	None.
Embraer Bandeirante	None.
Embraer Brasilia	Overhead bins in the cabin only along the right side of the cabin, above the double row of seats. Total volume of 32.1 cubic feet.
Fairchild Metro III	Baggage area/closet at the right forward end of the cabin opposite the doorway.
Piper Navajo	None.
Shorts 330	Overhead storage bins on each side of the cabin above the seats.

### LAVATORIES.

Only in the two larger aircraft, the Brasilia and the Shorts 330, are lavatories to be found. The other eight aircraft cabins are configured only for passenger and crew seating.



TABLE 7. COMMUTER AIRCRAFT LAVATORY AREAS

<u>Aircraft Type</u>	<u>Descriptions</u>
Bae Jetstream 3100	None.
Beech 99	None.
Beech 1900	None.
Cessna 402	None.
deHavilland Twin Otter	None.
Embraer Bandeirante	None.
Embraer Brasilia	Optionally available and installed in either the right forward or right rear part of the cabin area. Constructed of composite material lined with vinyl. Lavatory over a stainless steel pan, in turn, mounted to the honeycomb cabin floor structure.
Fairchild Metro III	None.
Piper Navajo	None.
Shorts 330	Located in the rear of the cabin area. Compartment panels of vacuum oven cure honeycomb sandwich panel 1/4 inch thick with 1/8 inch cell 1.5 lb./cubic foot Nomex* honeycomb. Facings a single 0.1mm laminate of phenolic resin pre-impregnated glass cloth on each side. Decor is 0.006 inch vinyl faced with 0.001 inch polyvinyl fluoride (PVF) (Schneller Aerfilm). Mouldings and trim pieces are vacuum oven cured multi laminate of phenolic resin pre-impregnated glass cloth (various thicknesses 0.02-0.06 inches). Visible surfaces painted with water base aircraft interior quality emulsion paint. Lavatory door a vacuum oven cure honeycomb sandwich panel with a 3/4 inch thick, 1/8 inch cell, 1.5 lb./cubic foot Nomex honeycomb core. Facing of two 0.1mm laminates of phenolic resin pre-impregnated glass cloth on each side. Decor of both sides covered with 0.006 inch vinyl faced with 0.001 inch PVF (Schneller Aerfilm).

**GALLEYS.**

As for lavatories, in the study group of aircraft, only the two largest aircraft, the Brasilia and Shorts 330, feature a galley area. This galley is typically small and suited for simple cabin service such as beverages.

\* Nomex is a registered trademark for DuPont.

TABLE 8. COMMUTER AIRCRAFT GALLEY AREAS

<u>Aircraft Type</u>	<u>Descriptions</u>
BAe Jetstream 3100	None.
Beech 99	None.
Beech 1900	None.
Cessna 402	None.
deHavilland Twin Otter	None.
Embraer Bandeirante	None.
Embraer Brasilia	Optionally installed at the left or right rear of the cabin or just aft of the cabin entry doorway on the left side.
Fairchild Metro III	None.
Piper Navajo	None.
Shorts 330	Located at the rear of the cabin. Locker doors are of vacuum oven cure honeycomb sandwich panel with 1/4 inch thick, 1/8 inch cell, 1.5 lb./cubic foot Nomex honeycomb core. Door facings are one 0.1mm laminate of phenolic resin pre-impregnated glass cloth on each side. Door decor is 0.006 inch vinyl faced with 0.001 inch PVF (Schneller Aerfilm). Galley Locker and caps are vacuum oven cured multi-laminate of phenolic resin impregnated glass cloth of various thickness (0.02-0.06 inch). Visible surfaces painted with water base aircraft interior quality emulsion paint. Locker top panels are vacuum oven cure honeycomb sandwich panel with 1/4 inch thick, 1/8 inch cell, 1.5 lb./cubic foot Nomex honeycomb core. Panel facings are one 0.1mm laminate of phenolic resin pre-impregnated glass cloth on each side. Panel decor is 0.001 inch PVF film (Tedlar).

FIREWALLS.

Manufacturers of the commuter aircraft surveyed report none of the aircraft have firewalls incorporated in the design of the cabin/fuselage area.

PARTITIONS.

In the ten aircraft, wood core sandwich panels are common, usually faced with aluminum or fiberglass. In the two newer design aircraft, the Brasilia and the Shorts 330, various combinations of thermoplastic are common. In the case of the Brasilia, newer materials were applied to the aircraft to achieve significant weight reductions.

TABLE 9. COMMUTER AIRCRAFT FUSELAGE AREA PARTITIONS

<u>Aircraft Type</u>	<u>Descriptions</u>
BAe Jetstream 3100	Partition at the forward edge of the main entry door between the cockpit and cabin constructed of honeycomb laminate. Construction of 0.78 inch Fiberlam (0.75 inch Nomex with epoxy skins of 0.015 inches) and of 0.28 inch Fiberlam (0.25 inch Nomex with epoxy skin of 0.015 inches).
Beech 99	No partitions. Sliding curtain separates pilots and the cabin, curtain fabric matching seat material such as vinyl or wool fabric.
Beech 1900	Sliding door partition separates pilots from cabin, and a partition with hinged top half separates the cabin from the rear baggage area. Partitions constructed of 1 inch aluminum honeycomb and veneer.
Cessna 402	Single partition at the rear of the cabin, separating the cabin and the tail cone area. The partition of plywood construction covered with high pressure laminate.
deHavilland Twin Otter	Forward partition between cabin and cockpit of 0.50 inch plywood core with formica (phenolic) facing. Sliding door in partition of 0.50 inch balsa wood core with formica facing. Rear bulkhead between cabin and baggage compartment of 0.020 inch aluminum and 0.032 inch Acrylic/PVC (Kydex) thermoplastic with naugahyde fabric covering and of 0.032 inch Acrylic/PVC (Kydex) thermoplastic.
Embraer Bandeirante	Sandwich panel behind pilots with aluminum facing on cockpit side over plywood and with formica facing on the cabin side. Partitions behind pilots with fabric curtain across the center opening.
Embraer Brasilia	Partitions between cockpit and cabin and between cabin and rear baggage area. Cockpit partition has a door at the center opening. Cockpit partition is nomex honeycomb with fiberglass facing on the cockpit side and vinyl facing on the cabin side. Baggage compartment partition is composite material faced with vinyl on the passenger side and Aramid (Kevlar) cloth and polyester resin (Gilliner) on the baggage side.
Fairchild Metro III	Partition between cabin and rear baggage compartment. Partition of plywood and steel with vinyl facing.
Piper Navajo	No partitions.

Partitions at the forward and rear of the cabin. The forward bulkhead upper panels and the entire rear bulkhead are constructed with vacuum oven cure honeycomb sandwich panel with 1/4 inch thick, 1/8 inch cell, 1.5 lb./cubic foot nomex honeycomb core. Facings are one ply 0.1mm laminate of phenolic resin pre-impregnated glass cloth on each side. Decor is 0.006 inch vinyl faced with 0.001 inch PVF (Schneller Aerfilm). The forward bulkhead center panel is vacuum oven cure honeycomb sandwich panel with 3/8 inch thick, 1/8 inch cell, 1.5 lb./cubic foot Nomex honeycomb core. Facings are two 0.1mm laminates of phenolic resin pre-impregnated glass cloth on each side. Decor is 0.006 inch vinyl faced with 0.001 inch PVF (Schneller Aerfilm). Forward bulkhead mouldings are vacuum oven cured multi-laminate of phenolic resin pre-impregnated glass cloth of various thickness (0.02-0.06 inches). Visible surfaces are painted with water base aircraft interior quality emulsion paint. The two flight compartment sliding doors are vacuum oven cure honeycomb sandwich panel with 3/16 inch thick, 1/8 inch cell, 1.5 lb./cubic foot Nomex honeycomb core. Facings are one ply 0.1mm laminate of phenolic resin pre-impregnated glass cloth on each side. Decor is 0.001 inch PVF (Tedlar).

#### MATERIALS

Following is a tabular comparison of the various materials reported, by manufacturers or aircraft operators, as used in selected applications.

#### LINING MATERIALS.

The description of materials represents those used at original manufacture. Refit of the interiors may result in substitution. Original Bandeirantes were fitted with leather due to its low cost, at that time, in Brazil.

TABLE 10. COMMUTER AIRCRAFT CABIN LINING MATERIALS.

<u>Aircraft Type</u>	<u>Material</u>
Bae Jetstream 3100	Lining for ceiling panels, sidewall jointstrips, passenger service unit (PSU) panel, and infill panel consists of two layers of fiberglass epoxy laminate. Ceiling panels, PSU panel and infill panel of 1/8 inch Nomex honeycomb with phenolic resin pre-preg fiberglass skins. Sidewall panels of 1/8 inch Nomex core with epoxy resin pre-preg fiberglass skins. Window reveal of 0.015 inch epoxy resin fiberglass. Decorative trim of headliners, sidewalls and PSU infill panels of PVF (Schneller Aerfilm) and Wardle Storey's Storey trim.
Beech 99	Acrylic/PVC (Kydex) with curtains of 56% rayon and 46% cotton.
Beech 1900	Acrylic/PVC (Kydex) with curtains of 56% rayon and 46% cotton.
Cessna 402	Combinations of leathers, vinyls and carpets. Sidewall upholstery backing panels of thin gauge aluminum (0.020 or less) and window escutcheons of thermoplastic sheet approximately 0.09 thick.
deHavilland Twin Otter	Lower cabin side (dado) panels of 0.025 aluminum covered with Naugahyde vinyl fabric and woven wool/nylon carpet. Sidewalls of 0.025 aluminum covered with Naugahyde vinyl fabric. Naugahyde covered ducts for cold air and 0.060 Acrylic/PVC (Kydex) covered overhead ducting.
Embraer Bandeirante	Liner of leather covered aluminum panels.
Embraer Brasilia	Liner of moulded fiberglass/ Kevlar*/ Nomex/ honeycomb/ carbon fiber with vinyl lining on passenger side.
Fairchild Metro III	Nomex honeycomb.
Piper Navajo	ABS/PVC polymer (Royalite).
Shorts 330	Cabin side and door panels of vacuum oven cure honeycomb sandwich panel with core of 1/4 inch thick, 1/8 inch cell, 1.5 lb./cubic foot Nomex honeycomb; facing of one 0.1mm laminate of phenolic resin pre-impregnated glass cloth on each side; and decor of 0.006 inch vinyl faced with 0.001 inch PVF (Schneller Aerfilm).

\* Kevlar is a DuPont registered trademark.

Ceiling panels of vacuum oven cure honeycomb sandwich panels with a core of 1/4 inch thick, 1/8 inch cell, 1.5 lb./cubic foot Nomex honeycomb; facings of one 0.1mm laminate of phenolic resin pre-impregnated glass cloth on each side; and decor of water base aircraft interior quality emulsion paint.

Forward exit sign boxes and forward vertical air conditioning duct covers of vacuum oven cured multi-laminate of phenolic resin pre-impregnated glass cloth (various thicknesses 0.02-0.06 inch). Visible surfaces covered with Schneller Aerfilm.

Door surrounds, framings and mouldings, and fairing pieces of vacuum oven cured multi-laminate phenolic resin pre-impregnated glass cloth (various thicknesses 0.02-0.06 inch). Visible surfaces painted with water base aircraft interior quality emulsion paint.

Window reveals and Passenger Service Unit (PSU) panels of vacuum formed polycarbonate (Lexan).

TABLE 11. COMMUTER AIRCRAFT BAGGAGE AREA LINING MATERIALS

Baggage liners are shown as original equipment. Once in service, operators report substitution of aluminum faced liners for improved durability.

<u>Aircraft Type</u>	<u>Material</u>
Bae Jetstream 3100	Three layers of fiberglass with epoxy resin. Lining of Schneller Aermat (fiberglass backed vinyl). Cabin stowage compartments of honeycomb and laminate. PVF decorative trim of Schneller Aerlam and Aerfilm, Wardle Storey's Storeytrim, Oberflex's Wood Veneer (fire retardant grade) and 100% Nylon woven pile loop fabric (Langenthal Multi Point).
Beech 99	Fuselage baggage area Aluminum sheet T2024 Alclad, 0.040 thickness. Belly pod of fiberglass with no liner.
Beech 1900	Aramid (Kevlar) cloth and polyester resin (Gilliner).
Cessna 402	Standard Alclad aluminum skin substructure lined with carpeting. Some stiffening done with aluminum honeycomb and fiberglass reinforcement.
deHavilland Twin Otter	Nose baggage area liner of 3/8 inch Balsawood core with fiberglass facing. Tail baggage area liner of 3/8 inch Balsawood core with aluminum liner.
Embraer Bandeirante	Aramid (Kevlar) cloth and polyester resin (Gilliner).
Embraer Brasilia	Aramid (Kevlar) cloth and polyester resin (Gilliner). Cabin overhead bins lined with vinyl. Floor of fiberglass with high density Nomex core, protected with corrugated aluminum sheets.
Fairchild Metro III	Vinyl covered sheet aluminum.
Piper Navajo	ABS/PVC polymer (Royalite).
Shorts 330	Front baggage compartment front, sides, and ceiling of vacuum oven cure honeycomb sandwich panel with a core of 3/16 inch thick, 1/8 inch cell, 1.5 lb./cubic foot Nomex honeycomb. Rear bulkhead of front baggage compartment of light alloy honeycomb sandwich panel with a core of 1.18 inch thick, 3/16 inch cell 5056 alloy 24G L72 aluminum skin on each side.

Aft baggage compartment panels of vacuum oven cure honeycomb sandwich panel with a core of 3/16 inch thick, 1/8 inch cell, 1.5 lb./cubic foot nomex honeycomb; an inner facing of two 0.1mm laminates of phenolic resin pre-impregnated glass cloth; and a decor of 0.001 inch PVF (Tedlar).

#### FLOOR COVERINGS.

With few exceptions, wool carpeting is the material used as floor covering in the ten selected aircraft.

TABLE 12. COMMUTER AIRCRAFT FLOOR COVERINGS.

<u>Aircraft Type</u>	<u>Material</u>
BAe Jetstream 3100	Side floor panels of 0.28 inch fiberlaminat (Nomex core with epoxy skins). Center aisle panels of 0.405 inch fiberlam. Main cabin carpeting is 100% wool face yarn with 100% synthetic backing (Langenthal Melair).
Beech 99	100 % wool carpeting.
Beech 1900	100 % wool carpeting.
Cessna 402	100% wool or rubber mats.
deHavilland Twin Otter	Woven wool/nylon carpeting.
Embraer Bandeirante	Fabric carpet of operators' choice.
Embraer Brasilia	Fabric carpet over carbon fiber/ nomex sandwich floor on mid-1987 and earlier aircraft. Aircraft from late 1987 changed floor to balsa wood core with fiberglass facing on each side.
Fairchild Metro III	Wool carpet.
Piper Navajo	20 inch Tiffany - tufted wool carpet with latex backing (General Motors Spec W2RB).
Shorts 330	Cabin seating area has 100 % wool, woven carpet with cut pile treated with fire retardant. Entrance/lavatory and cockpit areas have fiberglass backed vinyl floor covering (Schneller Aermat).



## MAJOR TRANSPARENCIES.

Acrylic polymer, commonly called Plexiglas, is the usual material for windows in the ten aircraft. The larger aircraft feature a layer, or lam, of glass on the outer face of the cockpit windscreens or windshields. Side windows are of acrylic polymer.

TABLE 13. COMMUTER AIRCRAFT TRANSPARENCY MATERIALS

<u>Aircraft Type</u>	<u>Material</u>
BAe Jetstream 3100	Inner and outer cabin transparencies of Perspex DTD 5592 acrylic polymer sheet.
Beech 99	Single pane cabin window of 0.050 inch acrylic polymer (Plexiglas).
Beech 1900	Single laminated pane of acrylic polymer.
Cessna 402	Standard window is laminate cast acrylic polymer.
deHavilland Twin Otter	Two layer cabin windows with an inner panel of acrylic polymer and an outer panel of acrylic/PVC alloy. Outer panel thickness is 0.08 inches. Cockpit side windows of 0.25 inch Plexiglas and front windscreens acrylic polymer laminate faced with glass.
Embraer Bandeirante	Cabin windows of single pane acrylic polymer with inner scratch shield of acrylic polymer. Cockpit windshield is glass/acrylic laminate if heated.
Embraer Brasilia	Cabin and cockpit side windows of single pane, stretched acrylic polymer with inner scratch shield of acrylic polymer. Cockpit windshield is glass faced laminated polycarbonate.
Fairchild Metro III	Acrylic polymer cabin windows.
Piper Navajo	Acrylic polymer cabin windows.
Shorts 330	Flat acrylic polymer sheet (Perspex) cabin windows. Moulded Perspex cockpit windows. Laminated acrylic faced with glass (Perplex). Earlier aircraft windshields not faced with glass.

## CABIN SEAT MATERIALS.

Seating universally uses urethane foam, though heat resistant wrappings are soon to be applied. These wrappings are not yet in use. Older design aircraft retain use of steel frame seating.

TABLE 14. COMMUTER AIRCRAFT SEAT MATERIALS

<u>Aircraft Type</u>	<u>Material</u>
BAe Jetstream 3100	Seat legs are formed sheet aluminum. Seat bottom is honeycomb aluminum panel with epoxy skins. Seat back is graphite epoxy resin as is the seat arm. Seat back cushion is open cell polyurethane foam and bottom cushion is open cell polyurethane foam combined with closed cell polyethylene foam (Ethafoam) providing flotation capability. A fire blocking layer of PBI/Kevlar/Nomex scrim felt is used on the cushions. Upholstery is usually 90% wool/ 10% nylon. 100% wool is used in some aircraft.
Beech 99	Steel frame with urethane foam cushioning. 100 % wool fabric with Zyrpro flame retardant treated covers with vinyl trim.
Beech 1900	100% wool fabric cover with Zyrpro flame retardant and vinyl trim.
Cessna 402	Pilots' seats are steel framed. Passenger seat frames are a composite material of Kevlar laminate (Enviroform). Cushioning is polyurethane foam and seat covering is 100% wool with vinyl trim.
deHavilland Twin Otter	Metal framed, urethane foam cushioned seats with naugahyde vinyl trim and upholstery. Kydex thermoplastic back panel of 0.040 inches thickness.
Embraer Bandeirante	Aluminum framed, urethane cushioned, leather covered seats. On later aircraft, seat covering material is optional.
Embraer Brasilia	Aluminum/carbon fiber/Kevlar seat frame with urethane cushion and fabric covering.
Fairchild Metro III	Steel and aluminum framed fiberglass bucket seats.
Piper Navajo	100 % wool fabric with vinyl trim.
Shorts 330	Tubular steel frame with foam cushions on nylon support diaphragms. 100 % wool covers.

### INSULATION MATERIALS.

Fiberglass cabin insulation is nearly universal in application.

TABLE 15. COMMUTER AIRCRAFT FUSELAGE INSULATION

<u>Aircraft Type</u>	<u>Material</u>
BAe Jetstream 3100	Cabin insulation is fiberglass Microlite PF 105W (0.6 pound per cubic foot) bagged in Orcofilm AN 18L.
Beech 99	Fiberglass.
Beech 1900	Fiberglass.
Cessna 402	Fiberglass.
deHavilland Twin Otter	Cabin not insulated.
Embraer Bandeirante	Fiberglass insulation with single coated vinyl foam tape (Scotchfoam) applied in high vibration areas such as next to the propellers. Earlier aircraft used rockwool rather than fiberglass.
Embraer Brasilia	Fiberglass insulation with single coated vinyl foam tape (Scotchfoam) applied in high vibration areas such as next to the propellers.
Fairchild Metro III	PVC/Nitrile foam (Ensolute) and fiberglass batting.
Piper Navajo	Fiberglass and Flexweave 1000 Cloth (fiberglass/vitreous aluminosilicate fibers with organic binders).
Shorts 330	Sound and thermal insulation of water repellant fiberglass with phenolic resin binder 0.61 lb./cubic foot. Covering of neoprene coated nylon cloth or nylon reinforced PVF film (on later aircraft).

### WIRE INSULATION MATERIALS.

Wiring conforms to various military specifications. Only in the Shorts 330 is use of Kapton insulated wiring reported.

TABLE 16. COMMUTER AIRCRAFT WIRING INSULATION

<u>Aircraft Type</u>	<u>Material</u>
BAe Jetstream 3100	Cabin and flight deck wiring as follows: Type 1 (Raychem Specification 44) - Specification Standard - wires: MIL-W-81044; cables MIL-C-27500 and MIL-C-7078. Type 2 (PTFE) Equipment wire - Specification Standard BSG 210, ISO 2032 and DEF STAN 61-12 Part 8 or MIL-W-16878. Type 5 (Aluminum cable) - Specification Standard - BNAE: L52-120, L52-125. Type 1 is the majority of the wiring. Type 2 used in some internal panel wiring. Type 5 is used for starter/generator feeders in wing and cabin areas.
Beech 99	Cabin and flight deck wiring routing, type and clamping in accordance with MIL-W-5088A. Non-shielded stranded wire of MIL-W-5086B or MIL-W-81044/9. Shielded stranded wire of MIL-C-7078B Class 4 or MIL-C-27500. Teflon insulated or high temperature stranded wire of MIL-W-22759/7, MIL-W-22759/8, MIL-W-25038, MILSPEC 17411, or MIL-W-16878D Type E. MIL-W-16878D Type E wire is not to be used in any harness which is supported by the structure or any application where it is exposed to abrasion.
Beech 1900	Cabin and flight deck wiring routing, type and clamping in accordance with MIL-W-5088A. Non-shielded stranded wire of MIL-W-5086B or MIL-W-81044/9. Shielded stranded wire of MIL-C-7078B Class 4 or MIL-C-27500. Teflon insulated or high temperature stranded wire of MIL-W-22759/7, MIL-W-22759/8, MIL-W-25038, MILSPEC 17411, or MIL-W-16878D Type E. MIL-W-16878D Type E wire is not to be used in any harness which is supported by the structure or any application where it is exposed to abrasion. All wiring of MIL-W-22759 and shielded wiring of MIL-C-27500.
Cessna 402	Cabin and flight deck wiring of MIL-W-81044/9 (Polyalkene-inner and polyvinylidene fluoride-outer). MIL-W-5086B/2 (Polyvinyl chloride-inner and PVC-glass-nylon jacket). MIL-W-81044/12 (Polyalkene-inner and polyvinylidene fluoride-outer. MIL-W-22759/8 (Polytetrafluoroethylene). MIL-W-5086A/1 (Polyvinylchloride-inner and extruded clear nylon jacket). MIL-W-22759/2 (Polytetrafluoroethylene). MIL-W-16878E/4 (Per Specification depending on "/X" number). Polytetrafluoroethylene (TFE) when specified conforms to L-P-403, Type III (ASTM-D-1457-83).

deHavilland Twin Otter	Cabin and flight deck wiring of MIL-W-5086 and MIL-W-22759/13.
Embraer Bandeirante	Cockpit avionics wiring is Tefzel extruded insulation of MIL-W-22759/35 24 gauge wire. Airframe wiring is MIL-W-5086/1 and /2 wiring with polyvinylchloride (PVC) insulation. High temperature wiring used in engine nacelles is MIL-W-22759/6 Polytetrafluoroethylene (TFE) insulated. Fire resistant nacelle wiring is MIL-W-25038 TFE insulated.
Embraer Brasilia	All wiring MIL-W-22759(TFE).
Fairchild Metro III	Ethylenetetrafluoroethylene (ETFE).
Piper Navajo	Cabin wiring since, 1980 MIL-W-81044/9; prior to 1980 MIL-W-5086/7. Flight deck wiring MIL-W-25038B.
Shorts 330	Cabin and flight deck wiring of three layers: PVC inner, glass braid center and nylon outer. On later aircraft, size 22 wire has polyimide (Kapton) insulation.

#### FUSELAGE SKIN THICKNESS.

Fuselage skin thickness of the cabin areas of the ten commuter aircraft is illustrated in figures 12 through 21. Thicknesses shown in the illustrations are measured in inches, e.g., .040 or .025 equal 0.04 inches and 0.025 inches.

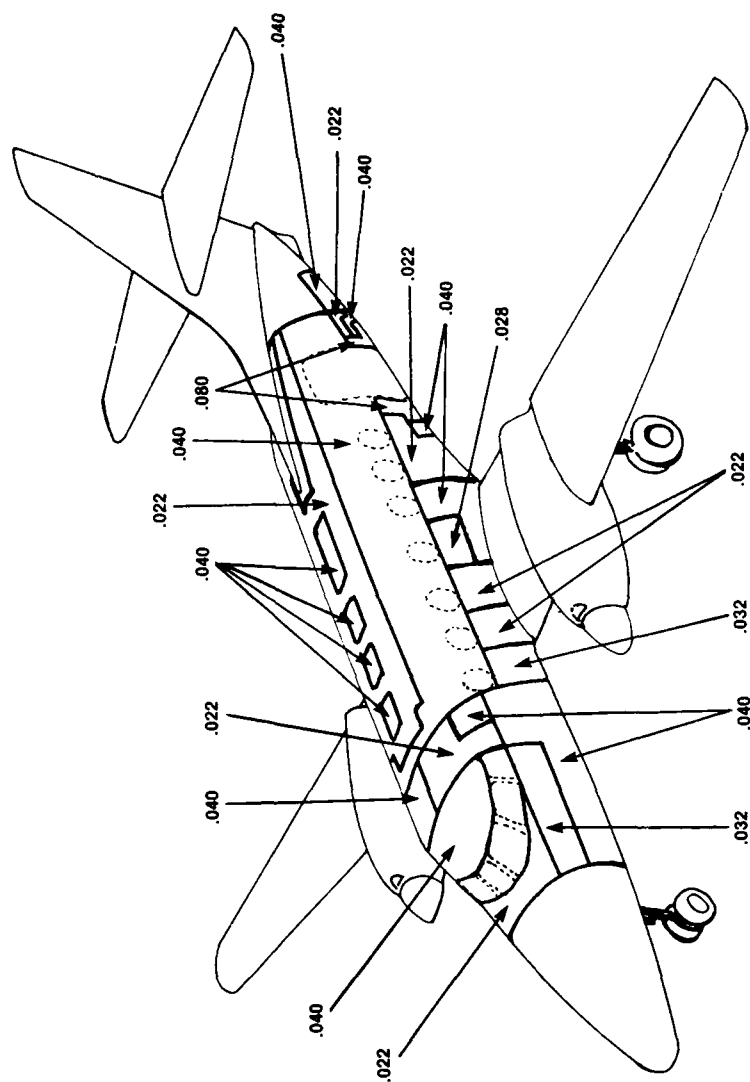


FIGURE 12. BAE JETSTREAM 3100 FUSELAGE SKIN THICKNESS

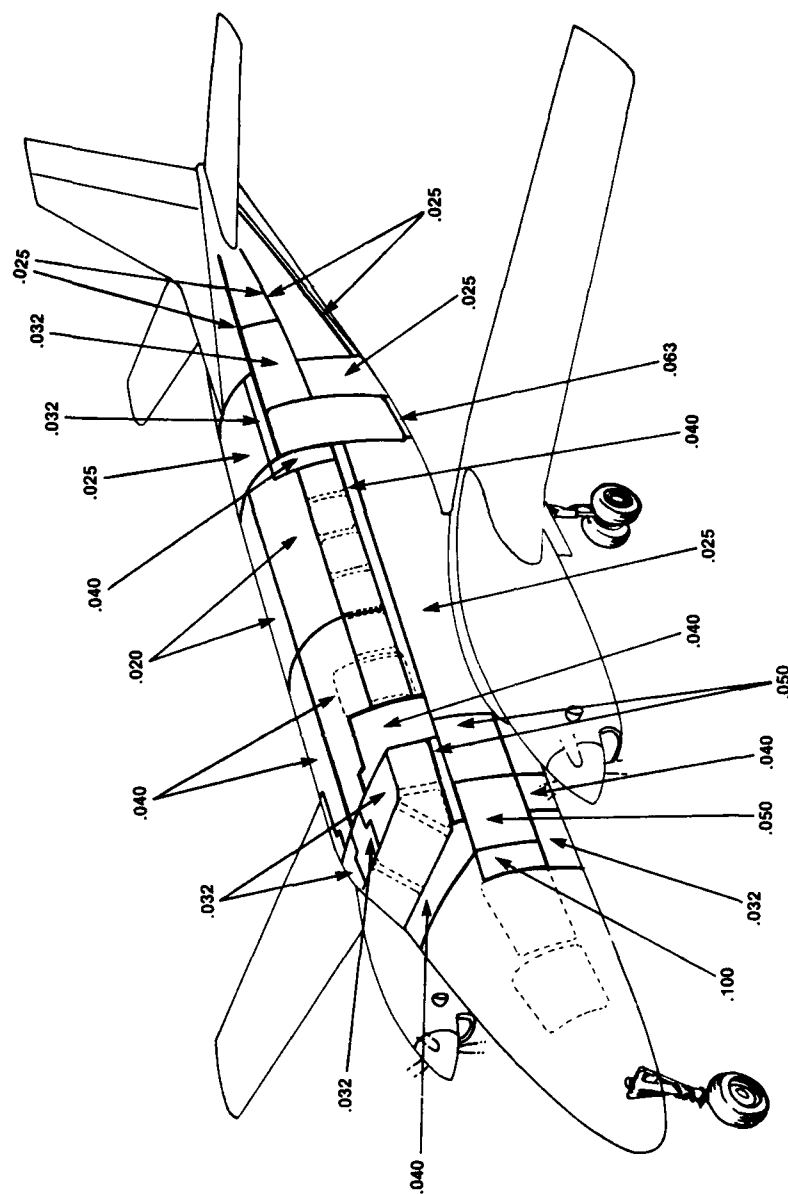


FIGURE 13. BEECH 99 AIRLINER FUSELAGE SKIN THICKNESS

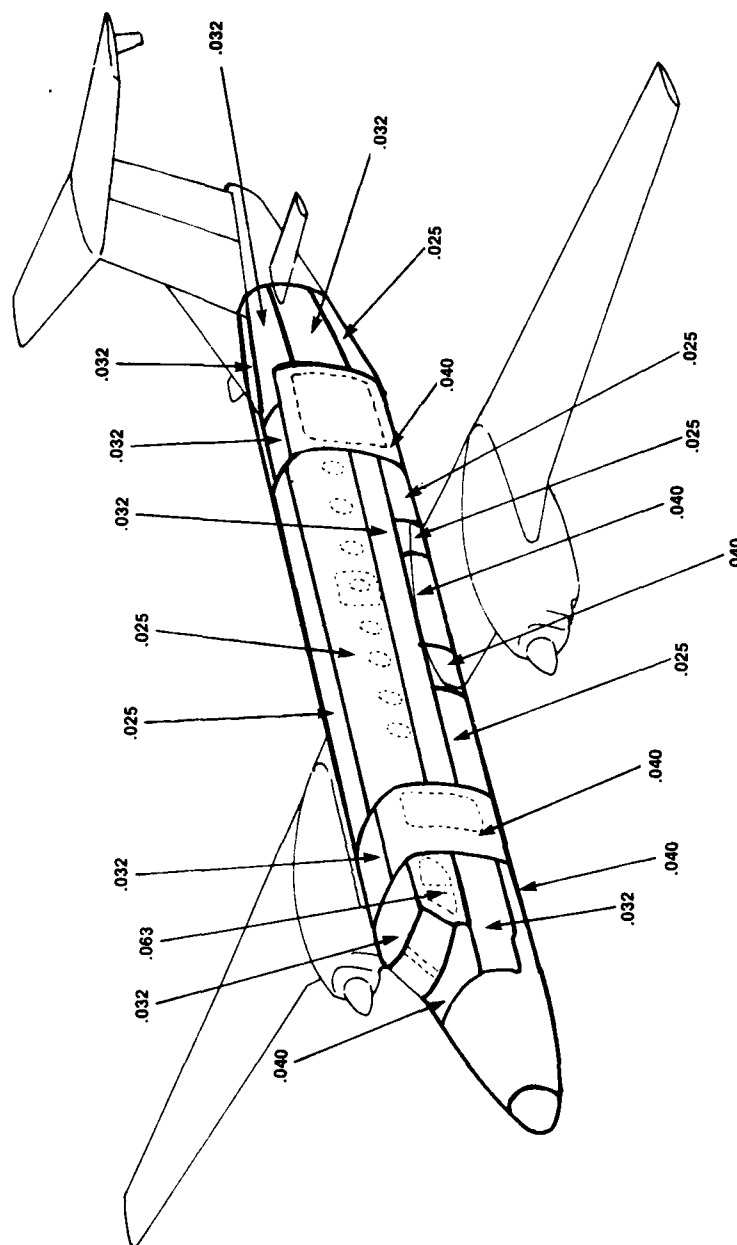


FIGURE 14. BEECH 1900 AIRLINER FUSELAGE SKIN THICKNESS



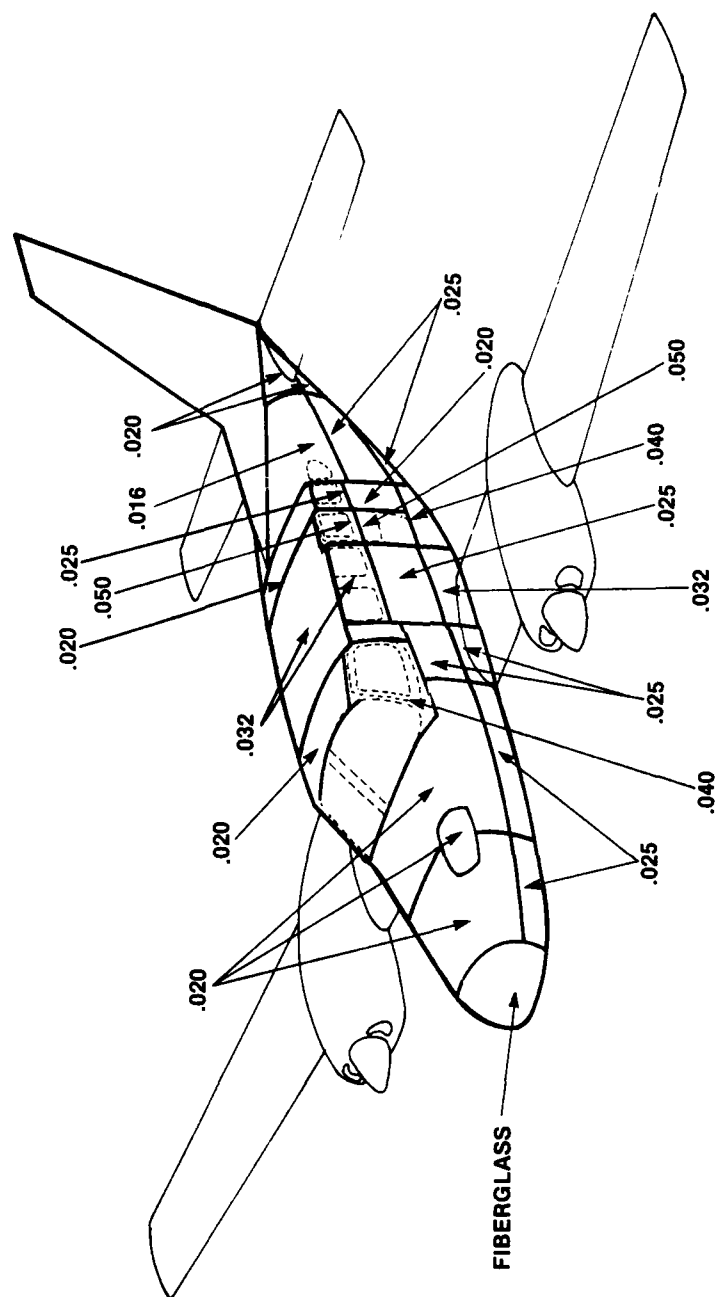


FIGURE 15. CESSNA 402 FUSELAGE SKIN THICKNESS





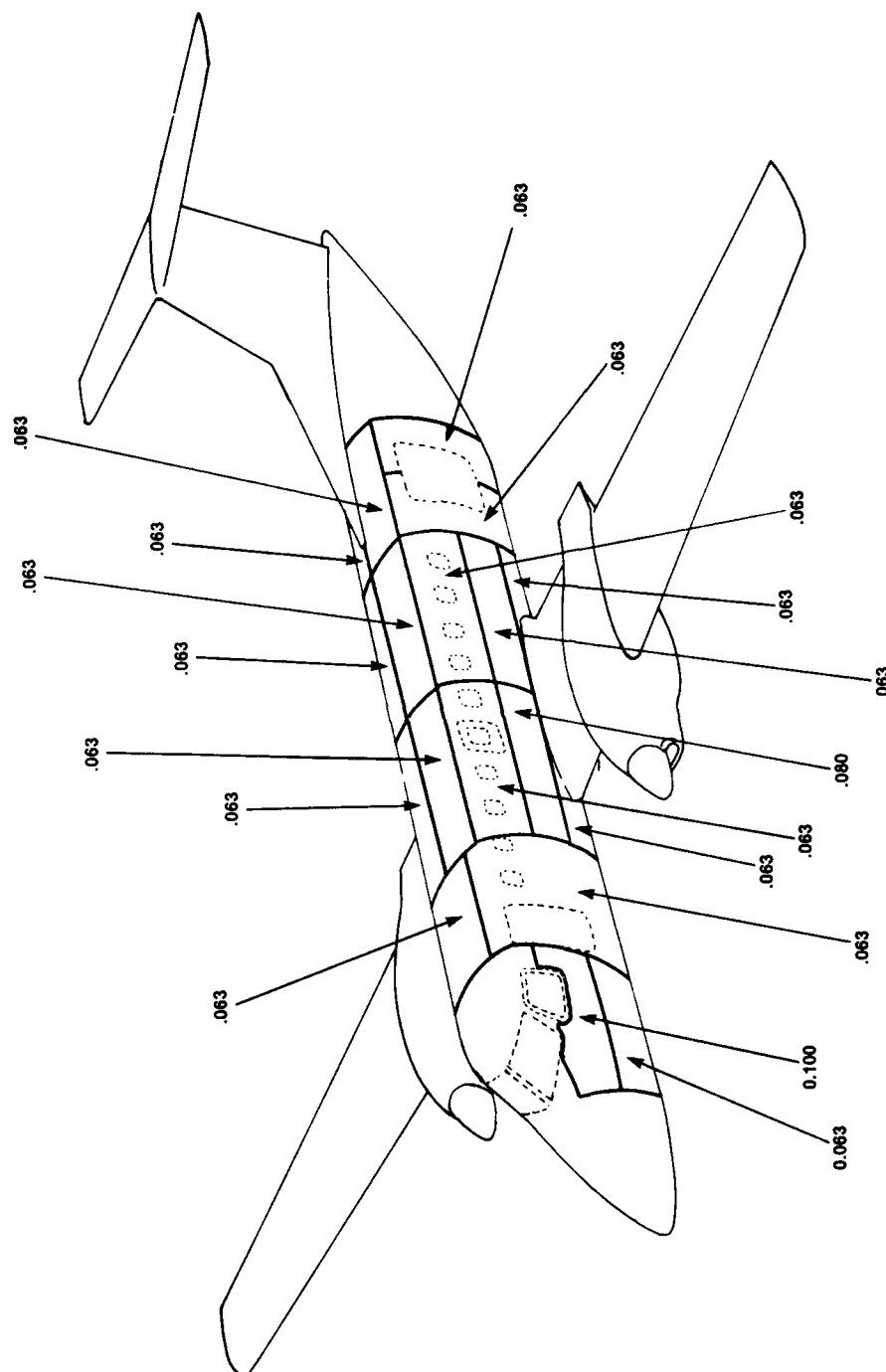


FIGURE 18. EMBRAER BRASILIA FUSELAGE SKIN THICKNESS

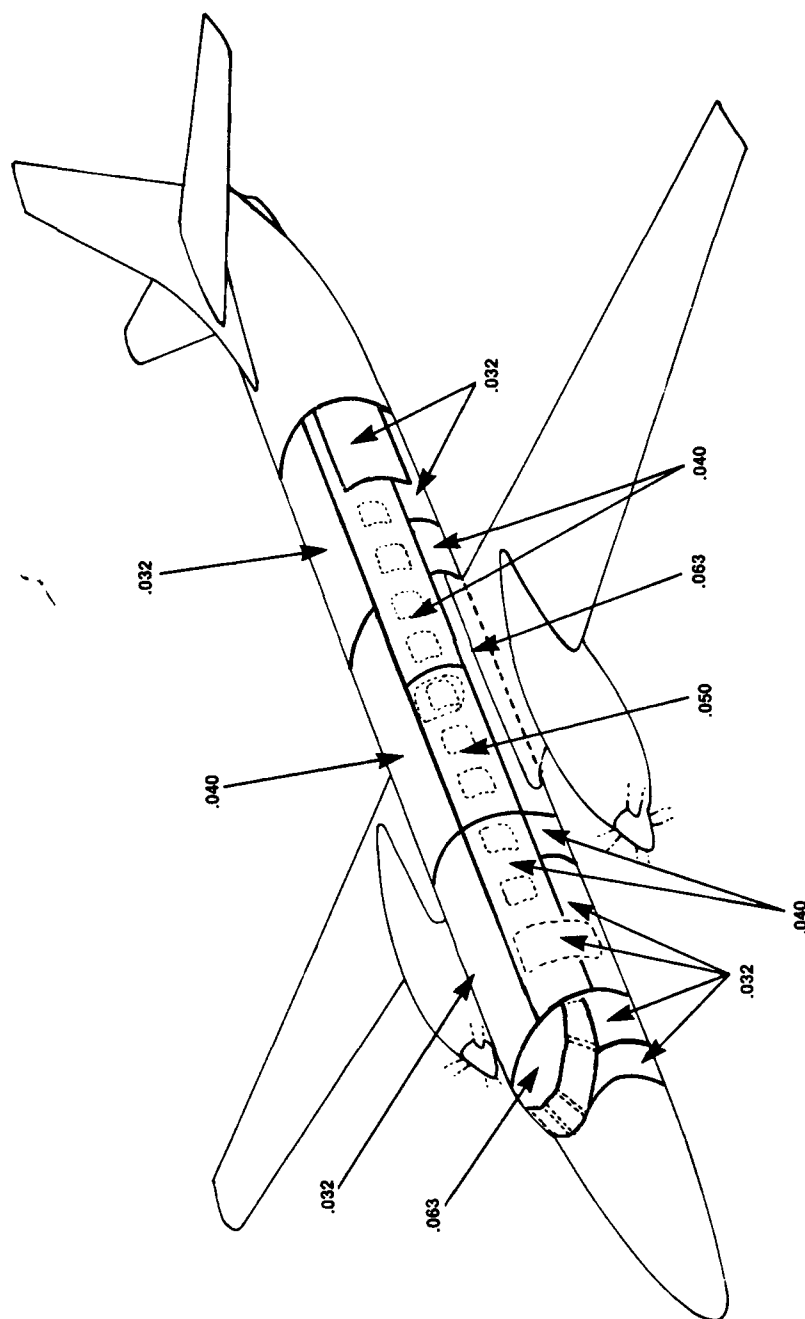
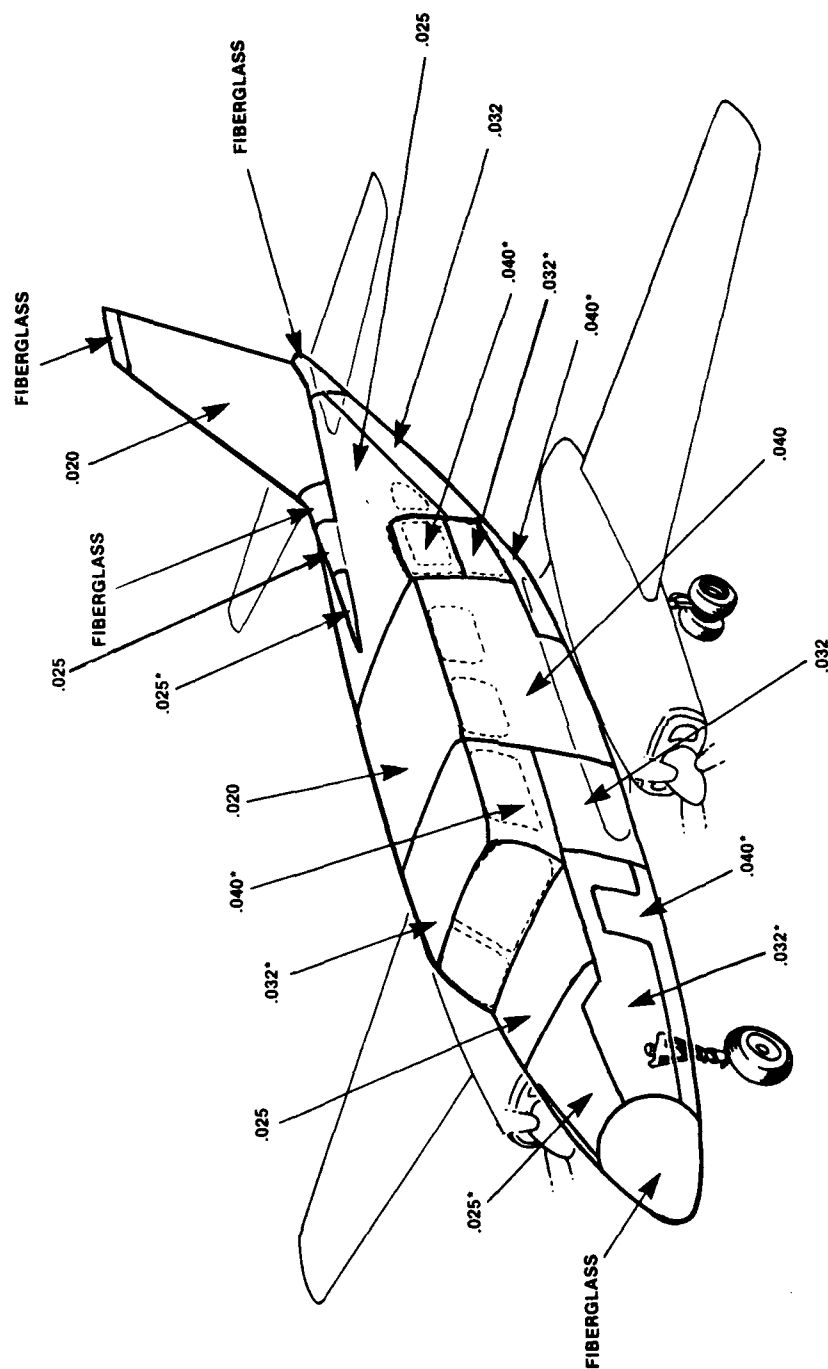


FIGURE 19. FAIRCHILD METRO III SKIN THICKNESS



\*NOTE: MATERIAL IS ALL 2024-T3 ALUMINUM EXCEPT WHERE NOTED BY \*, WHICH IS 2024-T4 ALUMINUM (HEAT TREATED AFTER FORMING)

FIGURE 20. PIPER NAVAJO FUSELAGE SKIN THICKNESS



## SYSTEMS

### FIRE DETECTION.

Types of fire detection systems vary, but new and larger aircraft feature continuous loop sensors featuring heat sensing through a pressurized gas. Embraer and Shorts aircraft feature baggage compartment smoke detectors; Beech offers these as an option on the Beech 1900.

TABLE 17. COMMUTER AIRCRAFT FIRE DETECTION SYSTEMS

<u>Aircraft Type</u>	<u>Descriptions</u>
Bae Jetstream 3100	Fault Free Fire Detection (FFF) type system of Gravinier HTL-heat sensing fire wire detecting changes in wire capacitance. System located in each engine nacelle.
Beech 99	Three photo-conductive cells sensitive to infrared rays are located in each nacelle and in the cabin center aisle floor aft of the main wing spar. Optional smoke detectors were available for the nose avionics compartment and adjacent to fuselage fire detectors.
Beech 1900	Temperature sensitive fire-loop located in each nacelle.
Cessna 402	Three heat sensitive detectors located in each engine nacelle.
deHavilland Twin Otter	Four thermal switches located in each engine nacelle.
Embraer Bandeirante	Two photocell smoke detectors in the cabin area and one in the baggage area. Older aircraft with three bimetallic heat sensors in the engine nacelles; newer aircraft have closed loop, pressurized gas heat sensing loops in the nacelle.
Embraer Brasilia	Cabin/baggage compartment smoke detectors in a labyrinth assembly containing a constant light source, a photocell, a test light and associated circuitry; two located in the cabin ceiling, one in the baggage compartment ceiling and one under the baggage compartment flooring. Engine nacelles have three heat sensors - one in the accessory section, one in the exhaust area and one in the landing gear wheelwell. Another heat sensor is located on the auxiliary power unit in the tail.



Fairchild Metro III	Bi-metal heat sensors in the engine compartments.
Piper Navajo	Piper Navajo Chieftain (piston powered) has no installed detection system. Turbine powered Navajo PA-31-1040 has three 450 degree fahrenheit thermal sensors in each engine compartment.
Shorts 330	Cabin smoke detectors: 2 in the forward cabin area, two in the aft cabin area and one in the baggage compartment. Both engine nacelles equipped with heat sensitive continuous-loop wire detectors.

#### FIRE SUPPRESSION.

Fire suppression for engines and auxiliary power units (APU) uses Halon 1301, except in the Shorts 330.

TABLE 18. COMMUTER AIRCRAFT FIRE SUPPRESSION SYSTEMS

<u>Aircraft Type</u>	<u>Descriptions</u>
BAe Jetstream 3100	Two fire bottles in each main wheelwell. Each bottle contains 4.5 pounds CBrF3 (Bromotrifluoromethane) / Halon 1301 charged by dry nitrogen. No discharge duration specified.
Beech 99	One cylinder containing 2 pounds of Halon located in each engine nacelle. Nozzled into the engine compartment with approximate discharge duration of 5 seconds.
Beech 1900	Two cylinders in each engine nacelle each containing 2 pounds of Halon and each with a discharge duration of approximately five seconds. Cylinders are discharged one at a time allowing up to four "shots" for one engine.
Cessna 402	One bottle in each nacelle containing 2.1 pounds Halon 1301 (Bromotrifluoromethane) with a discharge duration of no more than 2 seconds.
deHavilland Twin Otter	American Standard system of one bottle in each nacelle of 1.37 pounds Halon 1301 (CBrF3 - Bromotrifluoromethane) charged to 450 psi at 70 degrees Fahrenheit. Discharge duration not specified.

Embraer Bandeirante	Aircraft complying with SFAR 41 have one 2.5 lb. bottle of Halon 1301 in each wheelwell useable in each engine. Bottle provides a single charge of Halon to the engine accessory section.
Embraer Brasilia	6.5 pounds of Halon 1301 agent (CBrF3 Bromotrifluoromethane) per engine nacelle for the engine and wheelwell, and one one pound bottle of Halon 1301 at the tail mounted APU. No discharge duration specified.
Fairchild Metro III	One Halon 1301 (Bromotrifluoromethane) bottle with an agent amount of 3.5 pounds and a discharge duration of five seconds.
Piper Navajo	Navajo Chieftain has no engine fire suppressions system. The Navajo PA-31-1040 has a Halon 1301 system in each nacelle. Approximate discharge duration of four seconds.
Shorts 330	Four bottles of Halon 1211, two in each wing aft of the engine nacelle. 2.0 pound charge of agent per bottle. No discharge duration specified.

#### HAND EXTINGUISHERS.

Halon 1211 fire extinguishers have been installed in each aircraft except the EMB-110 Bandeirante. New Bandeirantes are not currently sold in the U.S. Operators may upgrade, voluntarily, to Halon 1211 extinguishers. In the Shorts 330 the Halon 1211 extinguishers can be directed into baggage areas through special couplings and tubing manifolds.

TABLE 19. COMMUTER AIRCRAFT HAND FIRE EXTINGUISHERS

<u>Aircraft Type</u>	<u>Descriptions</u>
BAe Jetstream 3100	Two extinguishers, one in the cockpit to the left of the left seat and one in the cabin behind the aft right passenger seat. Nitrogen charged Halon 1211 (BCF) with the cockpit bottle holding 5.4 pounds of agent and the cabin bottle holding 6.3 pounds of agent.
Beech 99	Two extinguishers, one under the right cockpit seat and one behind the aft left or right passenger seat in the cabin. Each bottle is a two pound Halon 1211 bottle.

Beech 1900	Two 2 pound Halon 1211 bottles, one under the right cockpit seat and the other next to the front entry door.
Cessna 402	One 2.5 pound Halon 1211 bottle beneath the right cockpit seat.
deHavilland Twin Otter	Two 2 pound Halon 1211 bottles, one on the cockpit floor between the seats and one on the right half of the passenger cabin door.
Embraer Bandeirante	A 2.2 pound carbon dioxide extinguisher bottle mounted on the pilot's seat back and one dry chemical extinguisher bottle behind the rear passenger seat and mounted on the bulkhead (SFAR 41 aircraft).
Embraer Brasilia	Two 2.5 pound Halon 1211 bottles, one behind the left cockpit seat and the other below the flight attendant seat at the forward entry door.
Fairchild Metro III	Two 2.5 pound Halon 1211 bottles, one behind the left cockpit seat and the other next to the front entry door.
Piper Navajo	One 2.5 pound Halon 1211 bottle under the right cockpit seat.
Shorts 330	Two 2 pound Halon 1211 bottles, one behind the right cockpit seat and one on the emergency hatch above the right rear exit door (by the galley).

#### OXYGEN SYSTEMS.

For nine of the ten commuter aircraft, use of cylinders of compressed (1850 psi) oxygen is standard. The Embraer Brasilia may be fitted with an optional oxygen system featuring oxygen generators; this installation is not common. Each, except the Shorts 330, either has or can have a fixed oxygen system installed. The Shorts 330 uses only two supplementary oxygen bottles for the pilots and passengers. The Bandeirante and the Twin Otter normally are equipped only with a portable oxygen bottle for each pilot.

TABLE 20. COMMUTER AIRCRAFT OXYGEN SYSTEMS

<u>Aircraft Type</u>	<u>Descriptions</u>
BAe Jetstream 3100	EROS 1409 liter (49.8 cubic foot) system. Cylinder storage behind the aft pressure bulkhead with line routing next to the cabin wall behind paneling and insulation. No special protective measures. Monel or stainless steel oxygen lines.
Beech 99	Cylinder storage in the nose. Lines routed overhead in the cabin with the cited protective measure being routing of oxygen lines away from other types of system lines. Lines of stainless steel with some aluminum.
Beech 1900	Twin cylinder storage, in the nose, of 76.5 cubic feet of compressed oxygen. Overhead line routing in the cabin wall away from other lines and behind paneling and insulation. Lines of stainless steel and some aluminum.
Cessna 402	Cylinder storage, in the nose, of 44 cubic feet of compressed oxygen (114.9 cubic foot optional system). Lines routed on the left side and top of cabin. Lines of 5052-0 and 6061-0 aluminum. Cessna design specification requires oxygen system installation not be in close proximity to fuel, oil and hydraulic systems. It is further directed that oxygen systems will not be contaminated by leaking fuel, oil and hydraulic fluids. The oxygen lines, fittings and equipment are required to be at least six inches away from fuel, oil and hydraulic systems. Deflector plates are stipulated where necessary to keep fuel, oil and hydraulic fluids from oxygen system components. Heating system ducts must be routed apart from oxygen system components or insulated to prevent heating of the oxygen system.
deHavilland Twin Otter	Commuter Twin Otters normally were not equipped with oxygen systems.
Embraer Bandeirante	Two portable cylinders (1850 psi and 115 cubic feet) for the pilots.

**Embraer Brasilia**

Cylinder storage of compressed oxygen (39 cubic feet at 1850 psi) in the flight attendant cabinet at the front of the cabin, supplemented by portable oxygen cylinders behind the right cockpit seat and next to the flight attendant seat. Line routed along the top of the cabin. Standard passenger oxygen system is two portable cylinders with two outlets each (adequate for 10 percent of cabin occupants). The optional system consists of oxygen chemical generators supplying oxygen for all occupants. There is one additional portable cylinder at the flight attendant station for therapeutic use.

**Fairchild Metro III**

High pressure (2000 psi) oxygen cylinder storage aft of the cargo compartment. From the cylinder to the selector valve the lines are routed along the side of the cabin between the inner liner and the skin. From the selector valve to the users the lines are run overhead in the cabin between the inner liner and the skin. Lines have local chafe guarding and threading compound is in accordance with Mil-T-5542B. Lines are of aluminum, steel, and copper. Passenger distribution lines are of nylon.

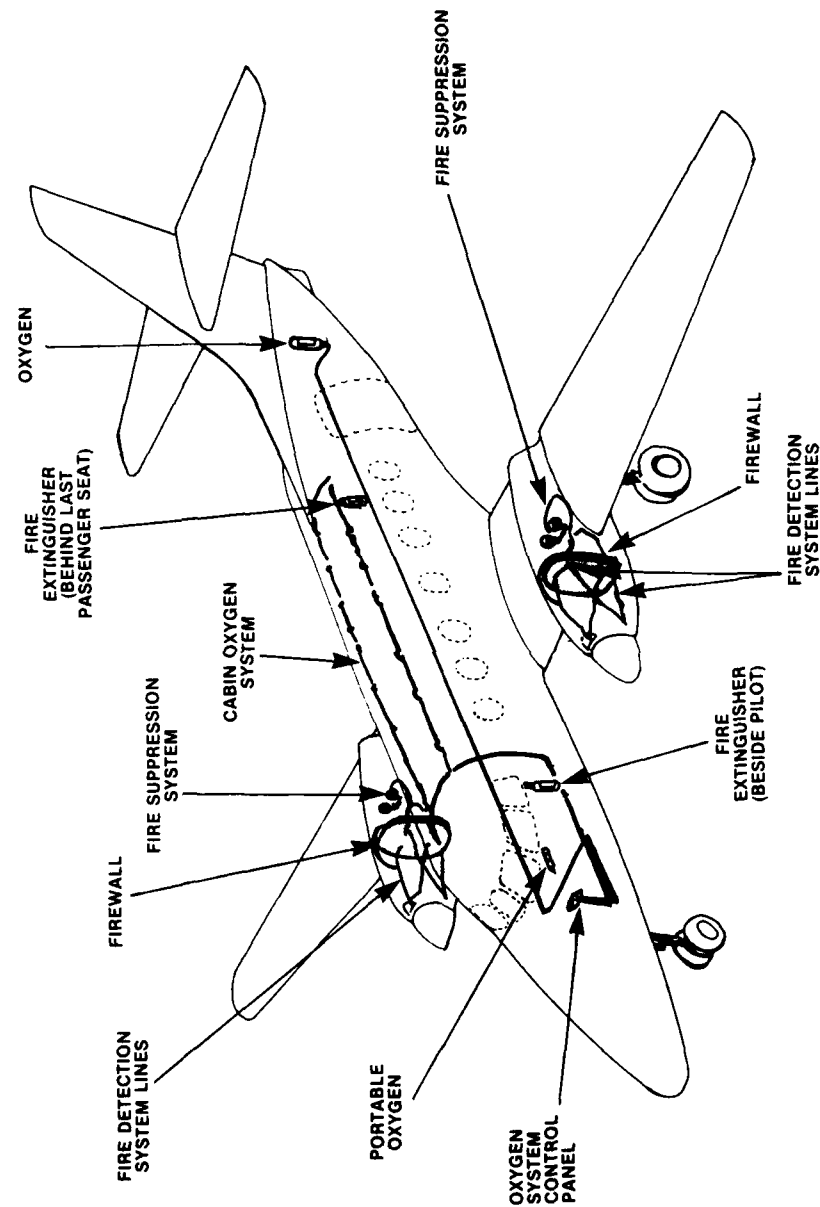
**Piper Navajo**

Cylinder storage of either 22 or 115 cubic feet of compressed oxygen in either the tail or nose. Lines are routed down the top center of the fuselage and are mounted in chafe grommets at passages through bulkheads. Lines are of 5050-0 aluminum.

**Shorts 330**

No fixed system is installed. Portable oxygen is available and stored in one bottle in the aft cabin storage area on the left side and at the right hand cockpit entrance from the cabin.

Fire suppression, fire detection, and oxygen systems are illustrated in figures 22 through 30. Figure 31 illustrates fire detection and suppression systems. Figure 32 illustrates oxygen system, and figure 33 illustrates fire suppression, fire detection, and oxygen systems.



**FIGURE 22. BAE JETSTREAM 3100 FIRE DETECTION, FIRE SUPPRESSION, AND OXYGEN SYSTEMS**

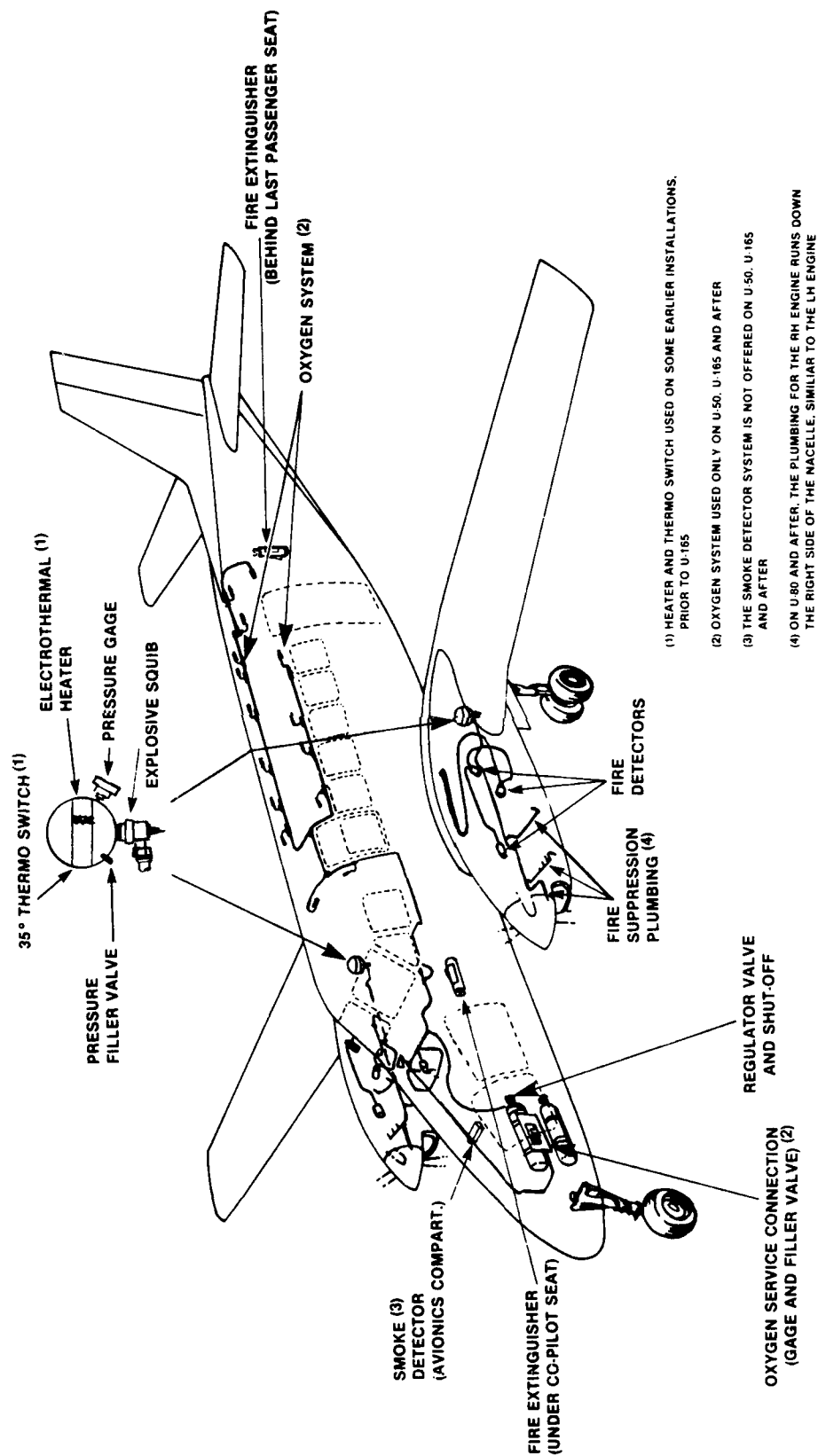
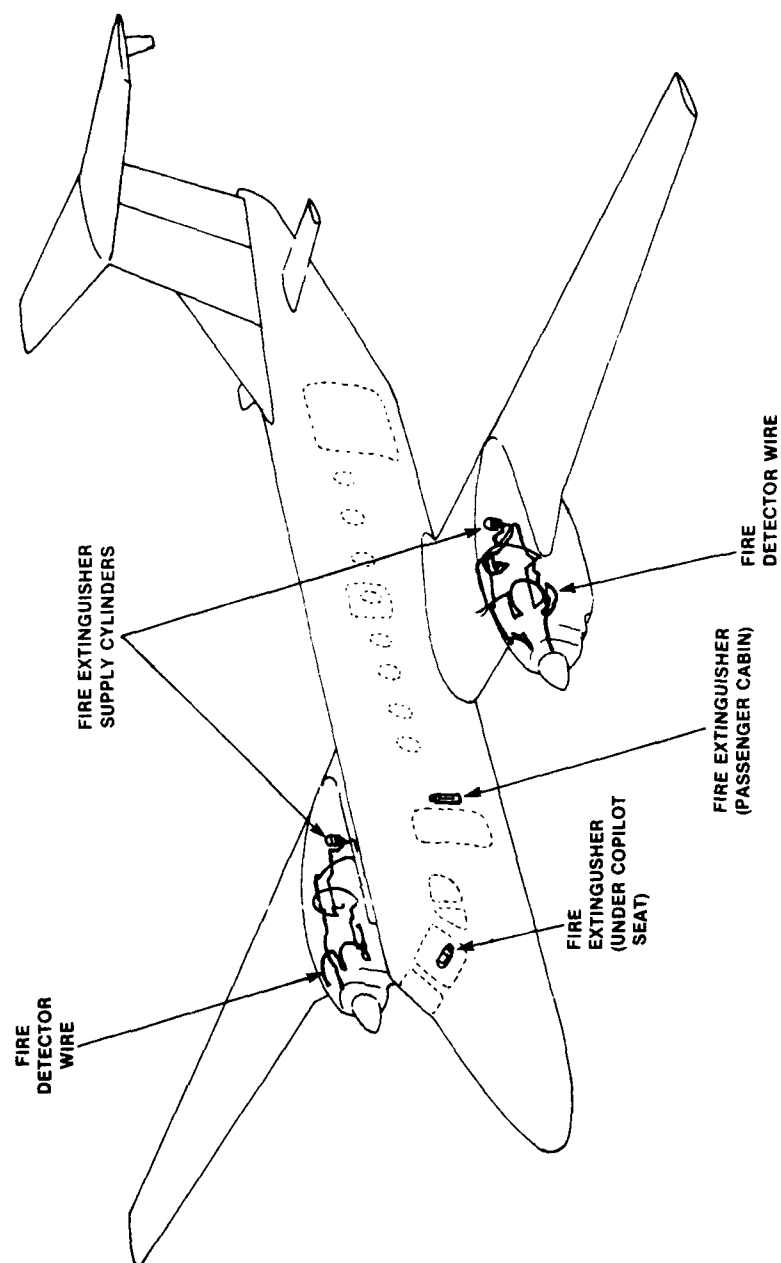
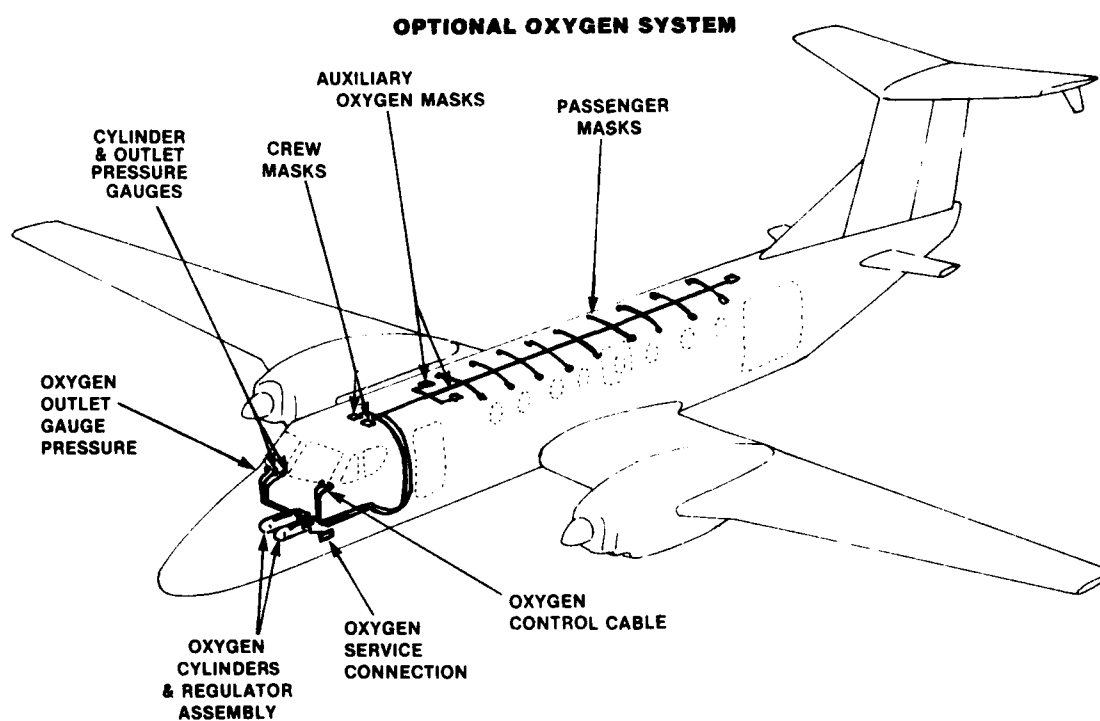
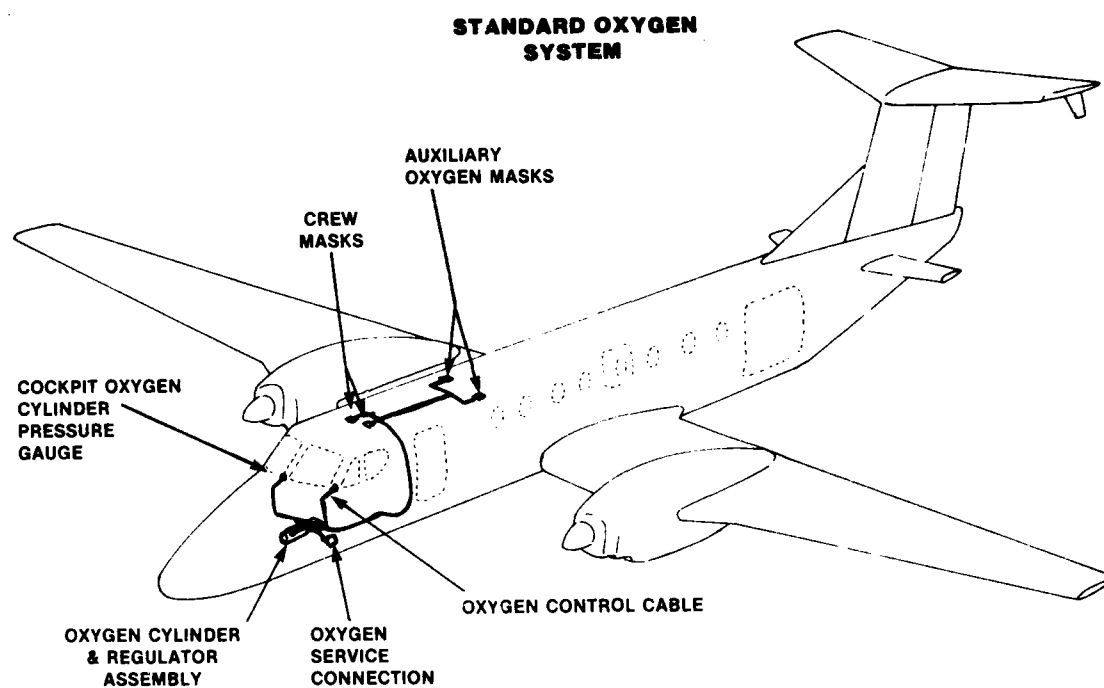


FIGURE 23. BEECH 99 AIRLINER FIRE DETECTION, FIRE SUPPRESSION, AND OXYGEN SYSTEMS

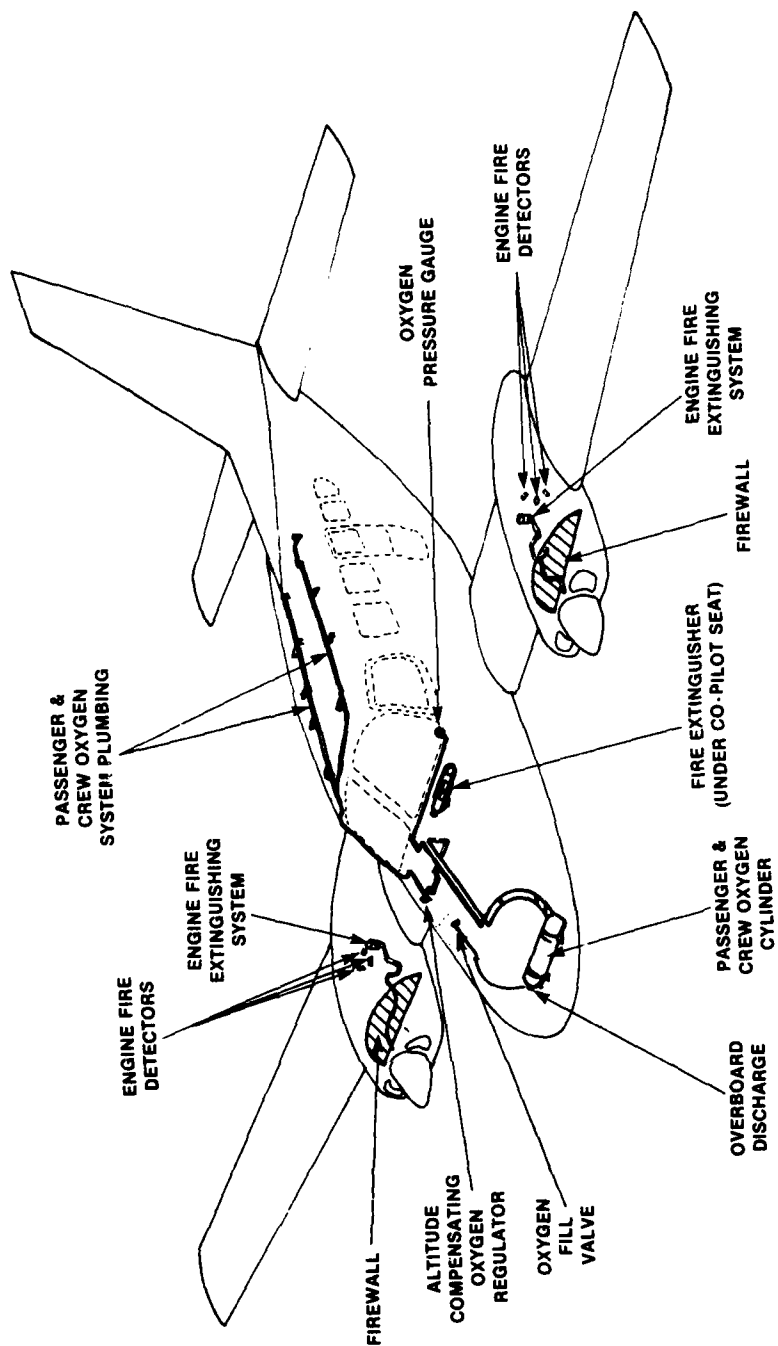


**FIGURE 24. BEECH 1900 AIRLINER FIRE DETECTION & SUPPRESSION SYSTEMS**





**FIGURE 25. BEECH 1900 AIRLINER OXYGEN SYSTEMS**



**FIGURE 26. CESSNA 402 FIRE DETECTION, FIRE SUPPRESSION, AND OXYGEN SYSTEMS**

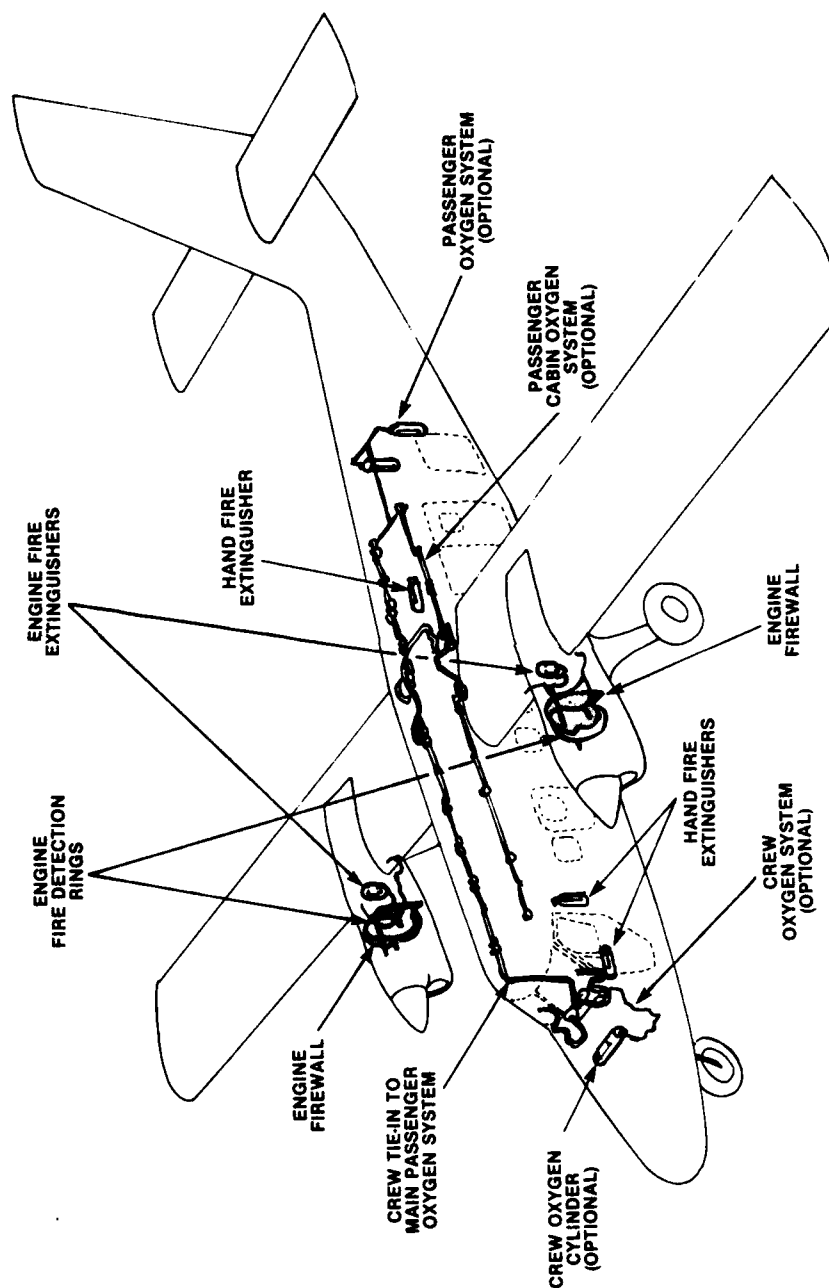
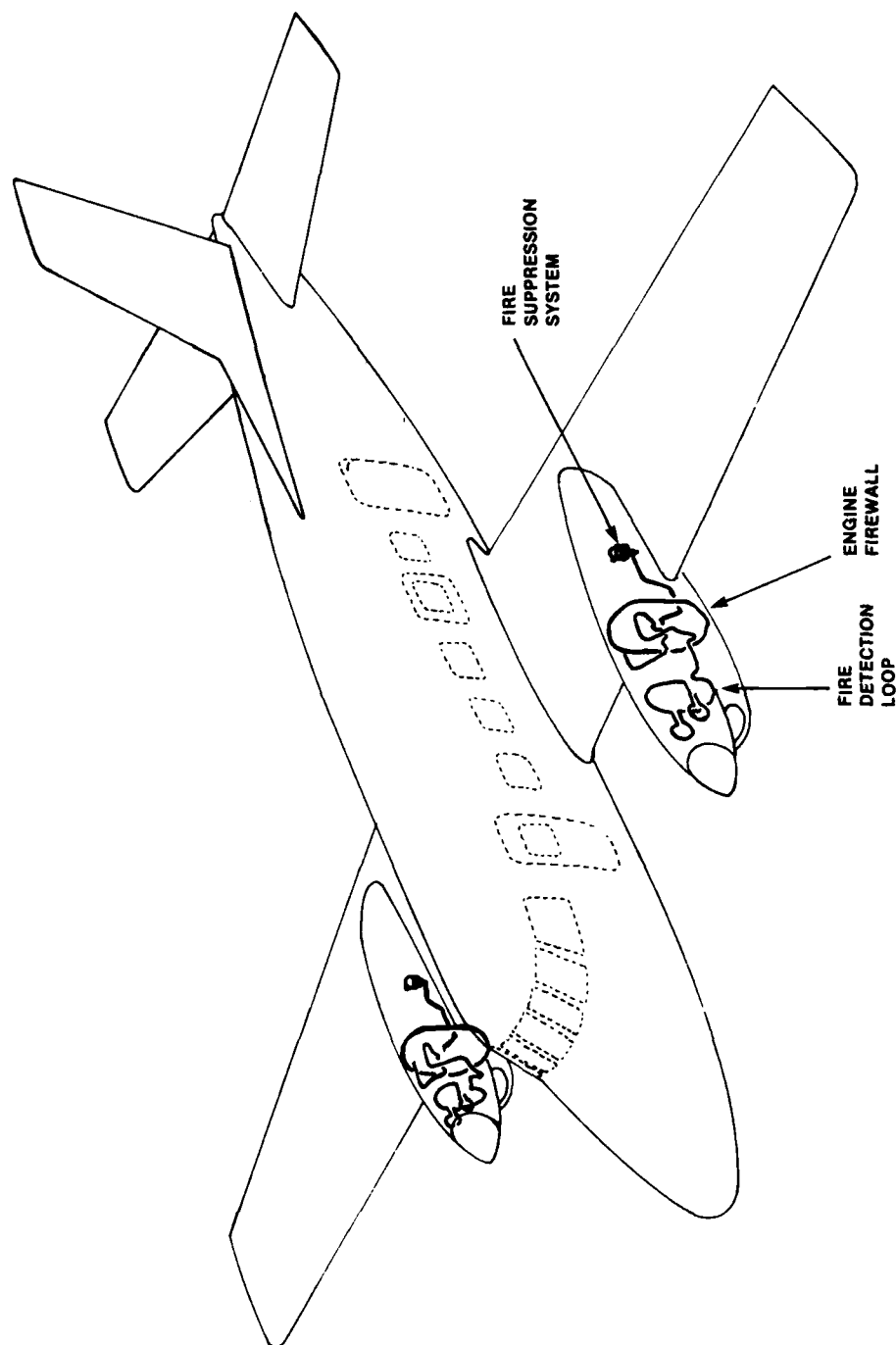
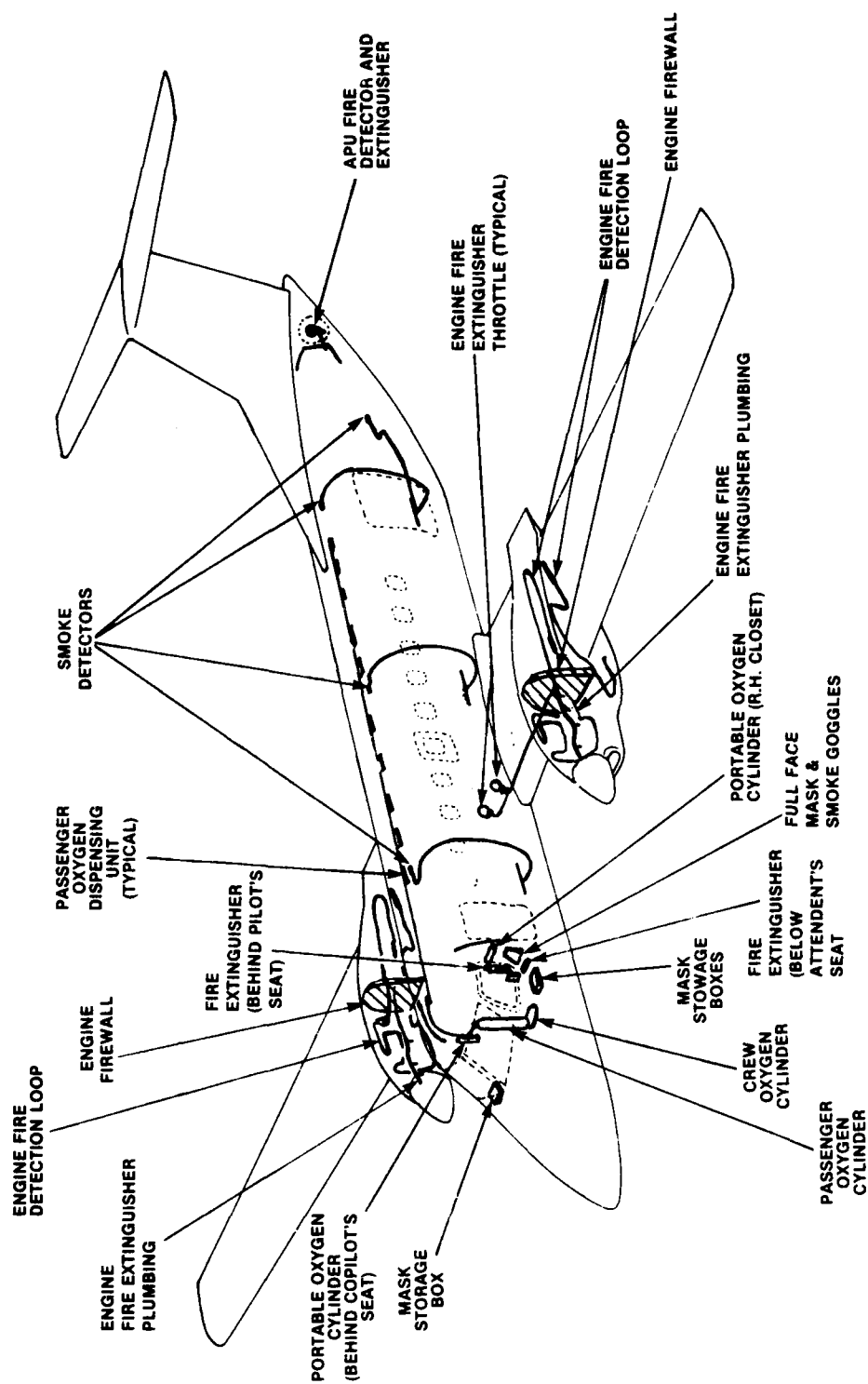


FIGURE 27. TWIN OTTER SERIES 300  
FIRE DETECTION, FIRE SUPPRESSION,  
AND OXYGEN SYSTEMS



**FIGURE 28. EMBRAER BANDEIRANTE FIRE DETECTION  
& SUPPRESSION SYSTEM**



**FIGURE 29. EMBRAER BRASILIA FIRE DETECTION, FIRE SUPPRESSION, AND OXYGEN SYSTEMS**

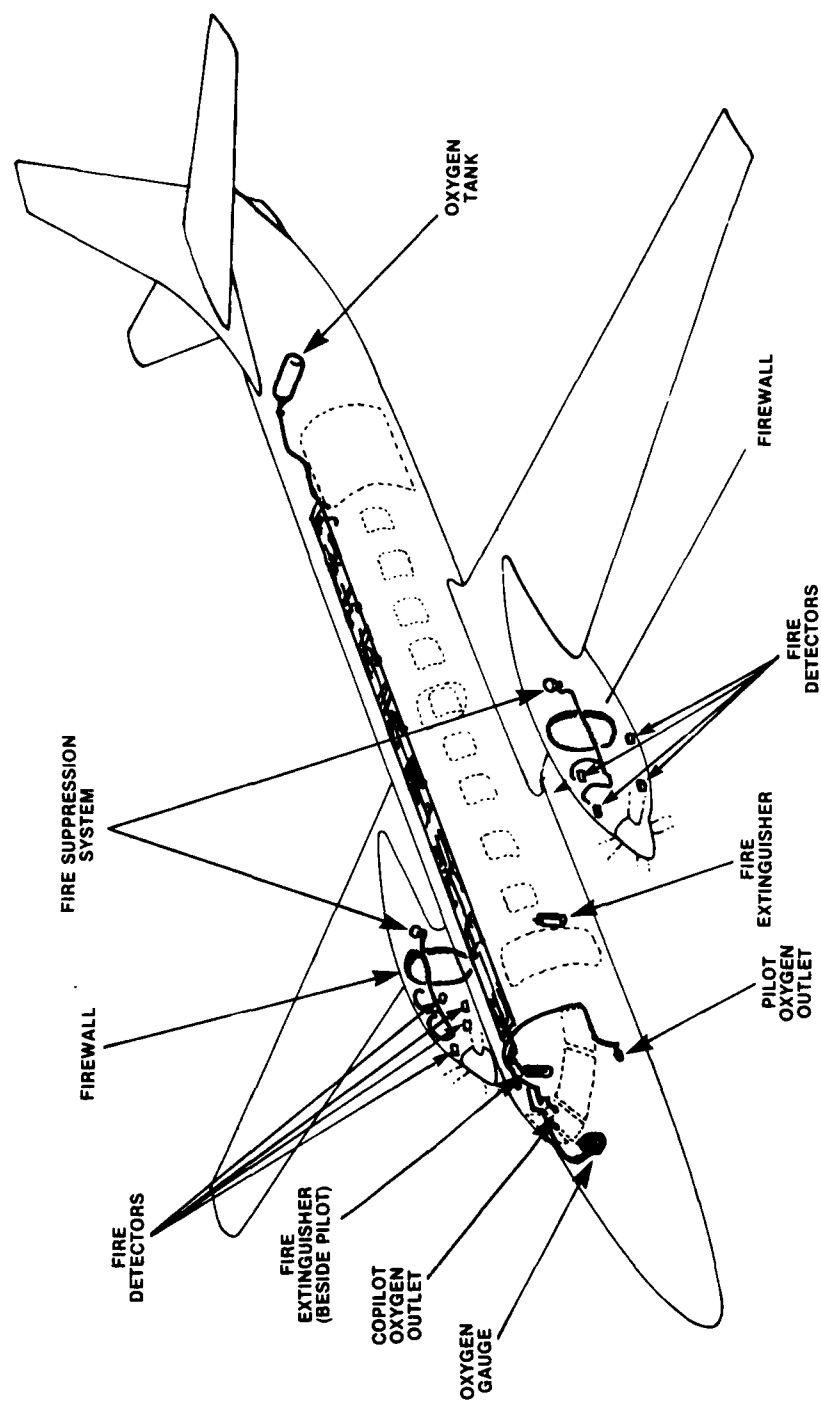
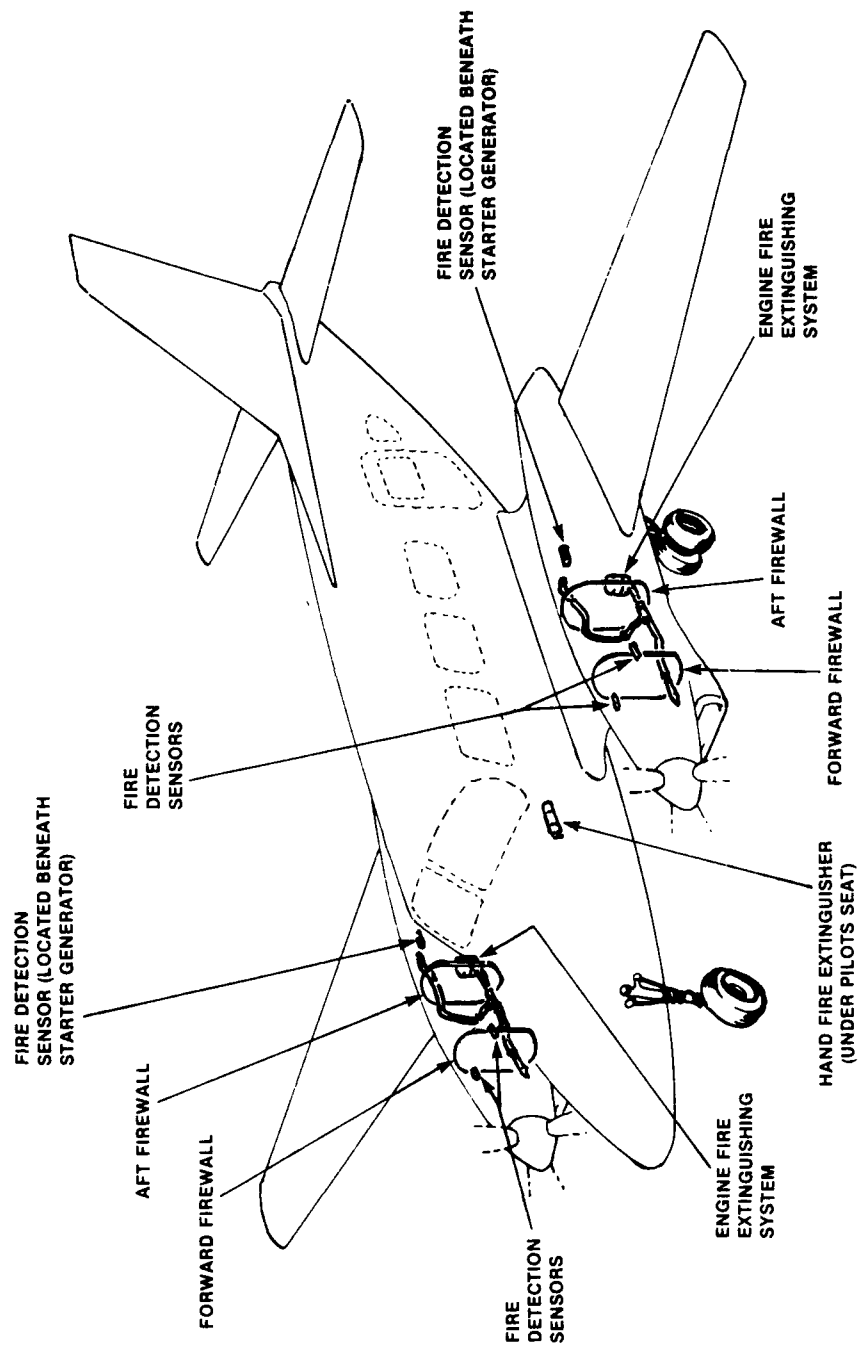
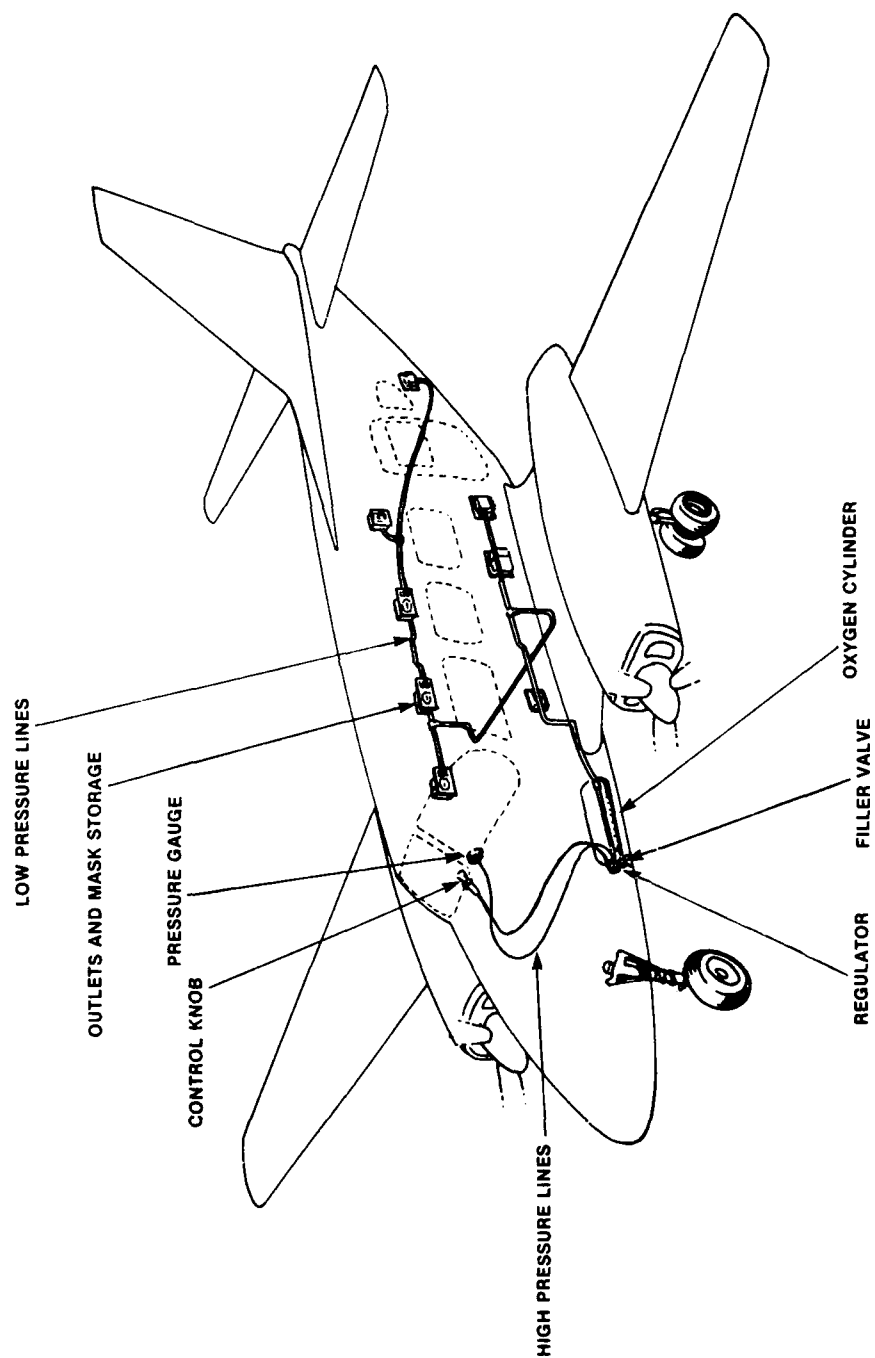


FIGURE 30. FAIRCHILD METRO III FIRE DETECTION,  
FIRE SUPPRESSION, AND OXYGEN SYSTEMS



**FIGURE 31. PIPER NAVAJO 1040 (TURBINE)  
FIRE DETECTION AND SUPPRESSION SYSTEMS**



**FIGURE 32. PIPER NAVAJO OXYGEN SYSTEM**



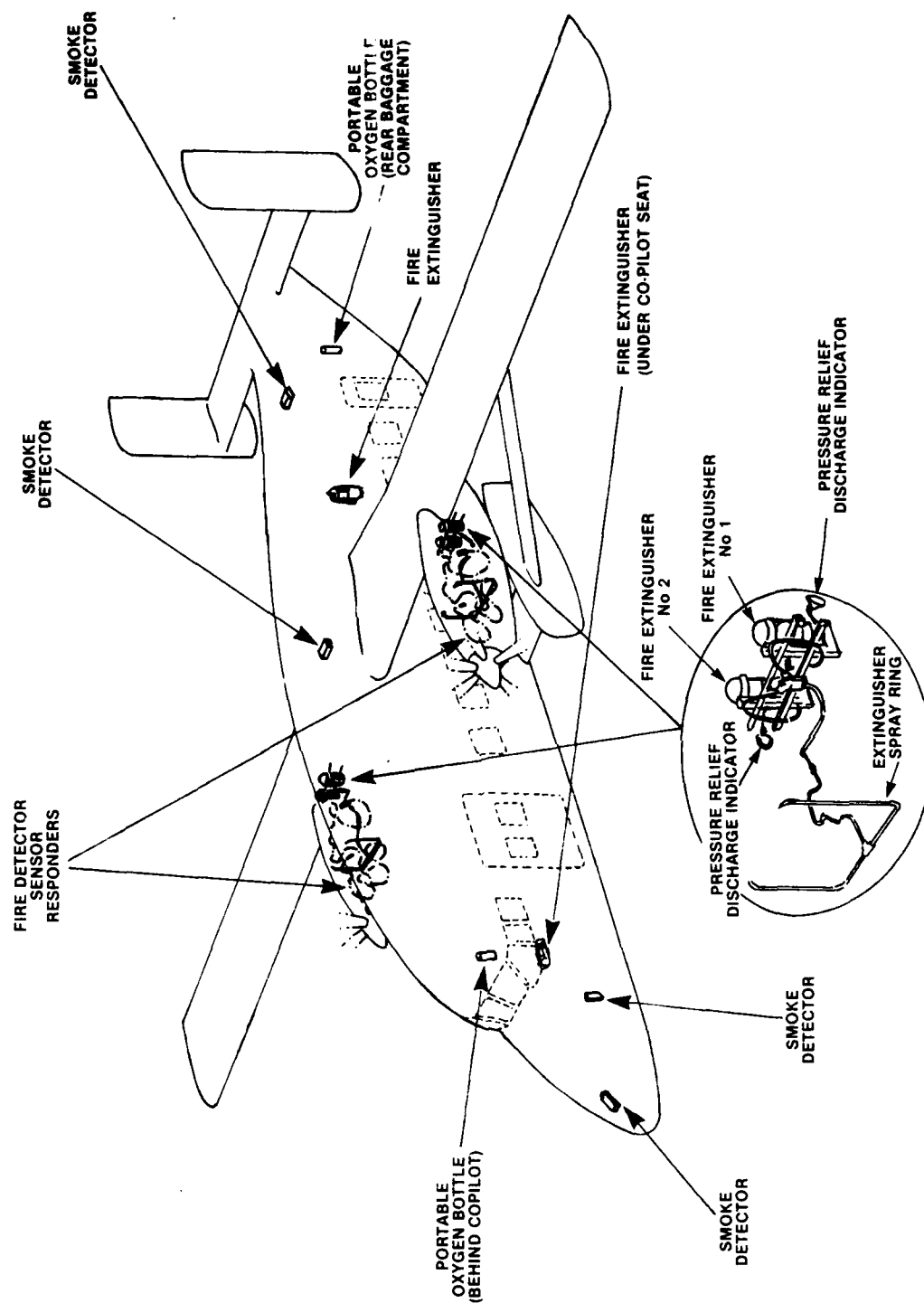


FIGURE 33. SHORTS 3-30 FIRE DETECTION, FIRE SUPPRESSION AND OXYGEN SYSTEMS

## VENTILATION SYSTEMS.

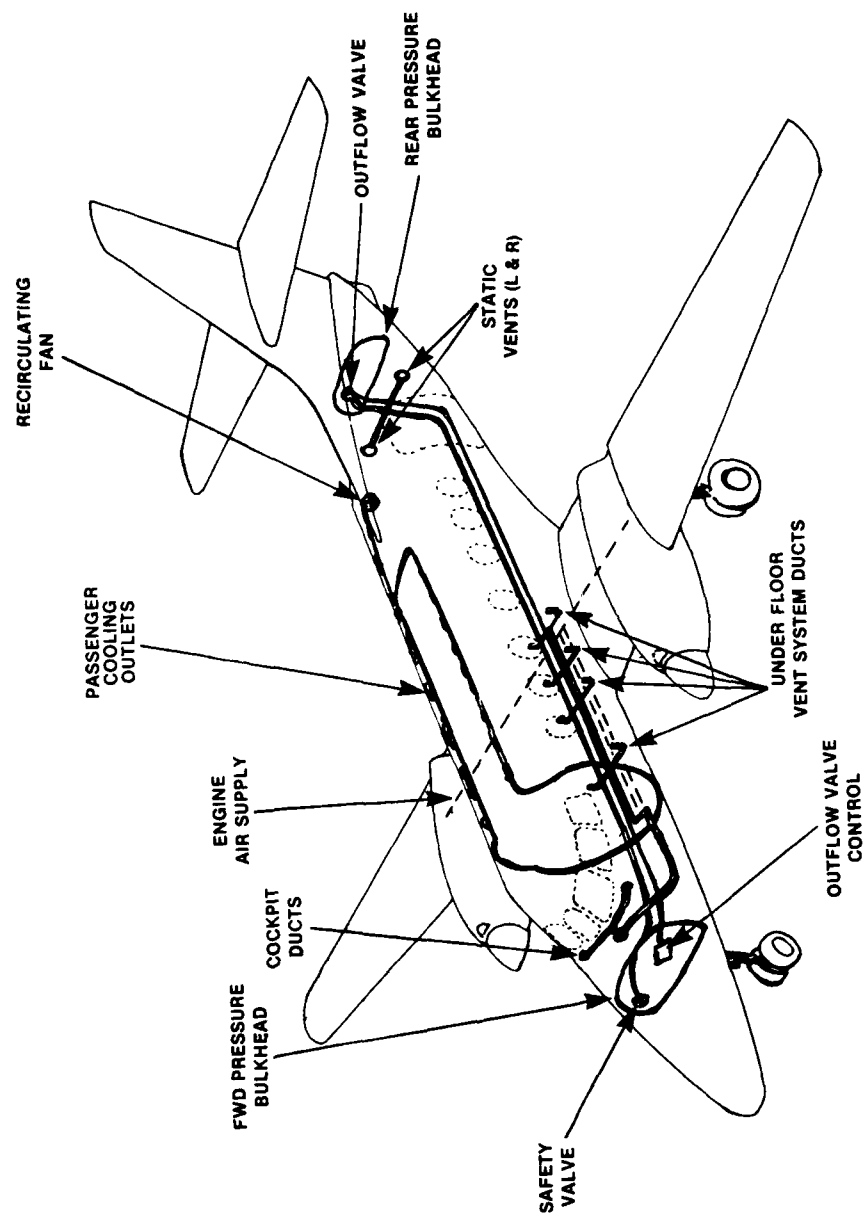
Older and smaller aircraft are unpressurized. Where the aircraft is turbine powered, engine bleed air is used for air conditioning and heating. Reciprocating engined aircraft, (CE-402 and Piper Navajo) use gasoline combustion heaters to warm the cabin air. These heaters are not equipped with fire detection or suppression systems.

TABLE 21. COMMUTER AIRCRAFT VENTILATION SYSTEMS

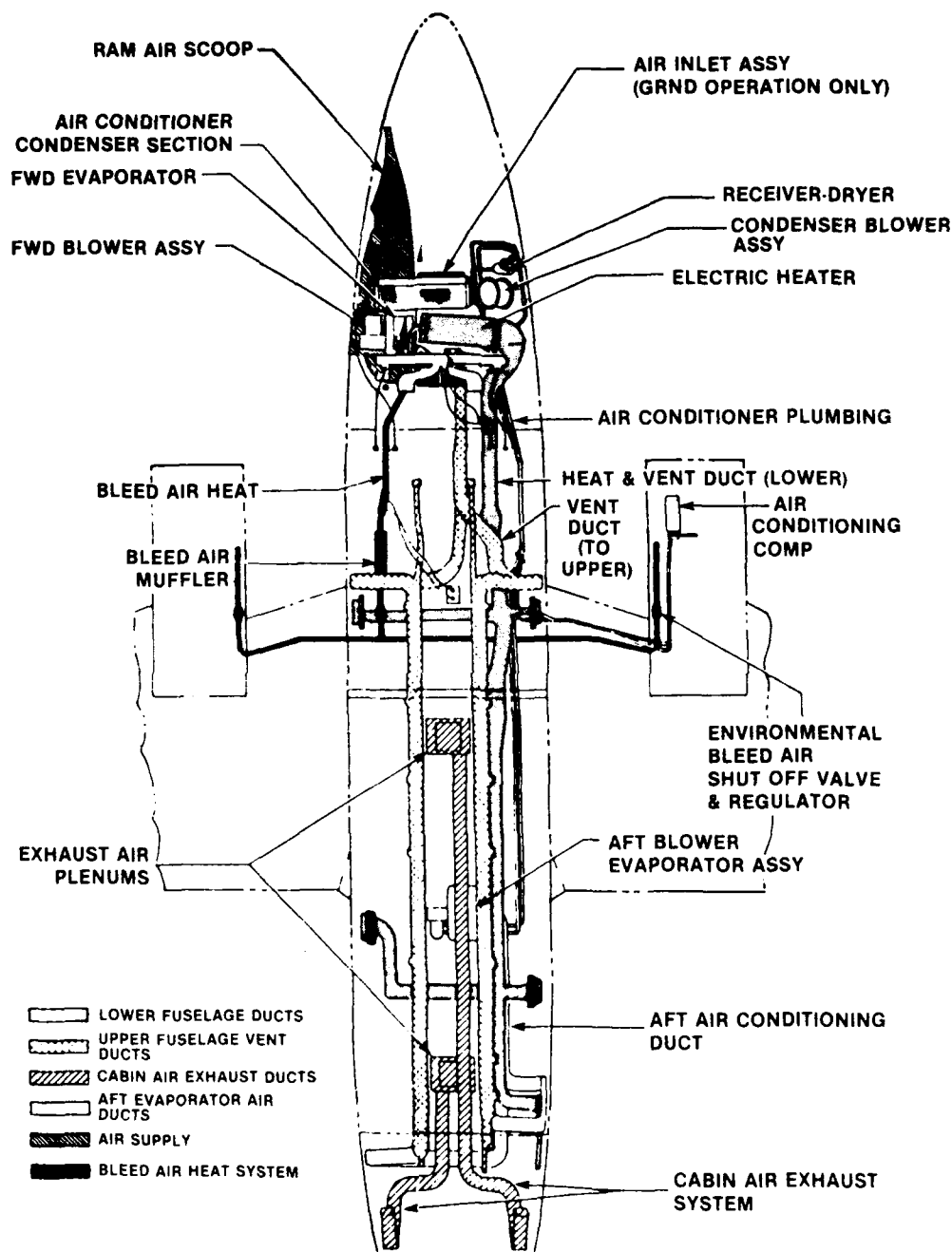
<u>Aircraft Type</u>	<u>Descriptions</u>
BAe Jetstream 3100	Pressurized aircraft with engine bleed air used for heated and cooled air, or with plain ram airflow of outside air. The air outflow is through a valve at the rear pressure bulkhead. Air change occurs in 2.17 minutes at 25,000 feet and 1.51 minutes at sea level. Air outflow rate is a Mass Flow Rate of 20 pounds per minute and Volume Flow Rate of 333 cubic feet per minute at 25,000 feet. At sea level the Mass Flow Rate is 36 pounds per minute and Volume Flow Rate is 480 cubic feet per minute. Duct material is of aluminum alloy, G.R.P. and proprietary lightweight ducting. G.R.P. is glass reinforced plastic -- in this case two layers of fiberglass cloth with phenolic resin. Flexible ducting of polyurethane coated nylon fabric supported by PVDF (polyvinyl difluoride) filament. Floor ducting of 0.28 inch fiberlaminat (Nomex core with epoxy fiberglass skins).
Beech 99	Unpressurized aircraft using ram air flow. Time for air change is 30 to 60 seconds depending on ram pressure. The air outflow location is an exhaust at the rear of the fuselage and the outflow rate is not specified. Duct material is fiberglass.
Beech 1900	Pressurized aircraft using either ram airflow or engine bleed air for heated or cooled air. Time for air change is 30 to 60 seconds, depending upon pressure differential with the air outside the cabin. The outflow valves are located in the aft cabin with outflow rate not specified. Duct material is fiberglass.
Cessna 402	Unpressurized aircraft using ram airflow from nose and dorsal fin intakes. Time for air change is variable depending upon adjustment of ventilation controls. Air outflow is through an exhaust at the rear of the cabin. Duct materials are fiberglass, aluminum sheet metal, flexible rubber ducting and some thermoform plastics.

deHavilland Twin Otter	Unpressurized aircraft using ram airflow collected from a scoop beneath the cockpit and distributed through a ducting system. Heat for the ram air is obtained from engine bleed air. Airflow rates are not known. Air exits from an exhaust at the top of the cabin center. Duct materials are 0.060 and 0.080 polycarbonate (Lexan).
Embraer Bandeirante	Unpressurized aircraft using engine bleed air for circulation after heating or cooling. Ram air circulation is obtainable with two NACA air inlets in the dorsal fin providing the air source.
Embraer Brasilia	Cabin and cockpit are supplied by separate air ducting with cross connecting capabilities. Pressurized (7.2 psi) aircraft using ram airflow and engine or APU bleed air for heating and cooling of recirculated air. Composite material ducting reinforced with fiberglass.
Fairchild Metro III	Pressurized aircraft (7.0 psi) using ram air and engine bleed air for heating and cooling of airflow. Bleed air from a single engine yields a time for air change of less than 6 minutes, while using dual engine bleeds yields a change in less than 3 minutes. The outflow valve is located in the aft pressure bulkhead behind the cargo compartment. Air outflow rate is 22 lbs. minimum with the rate dependent on outside air temperature, cabin temperature, cabin altitude, pressure altitude, throttle settings and the number of environmental control unit (ECU) packs operating. Duct material is aluminum and silicone impregnated fiberglass.
Piper Navajo	Unpressurized aircraft using ram airflow. Outflow location is venting at the tail with no rate specified. Ducting is of fiberglass.
Shorts 330	Unpressurized aircraft using ventilation blowers and no ram air. Time for air change is unspecified and outflow is from the rear of the cabin at a rate of 15 to 25 lb. per minute. Duct material is reinforced, insulated plastic.

Figures 34 through 43 illustrate ventilation systems.



**FIGURE 34. BAE JETSTREAM 3100 VENTILATION SYSTEM**



**FIGURE 35. BEECH 99 AIRLINER VENTILATION SYSTEM**

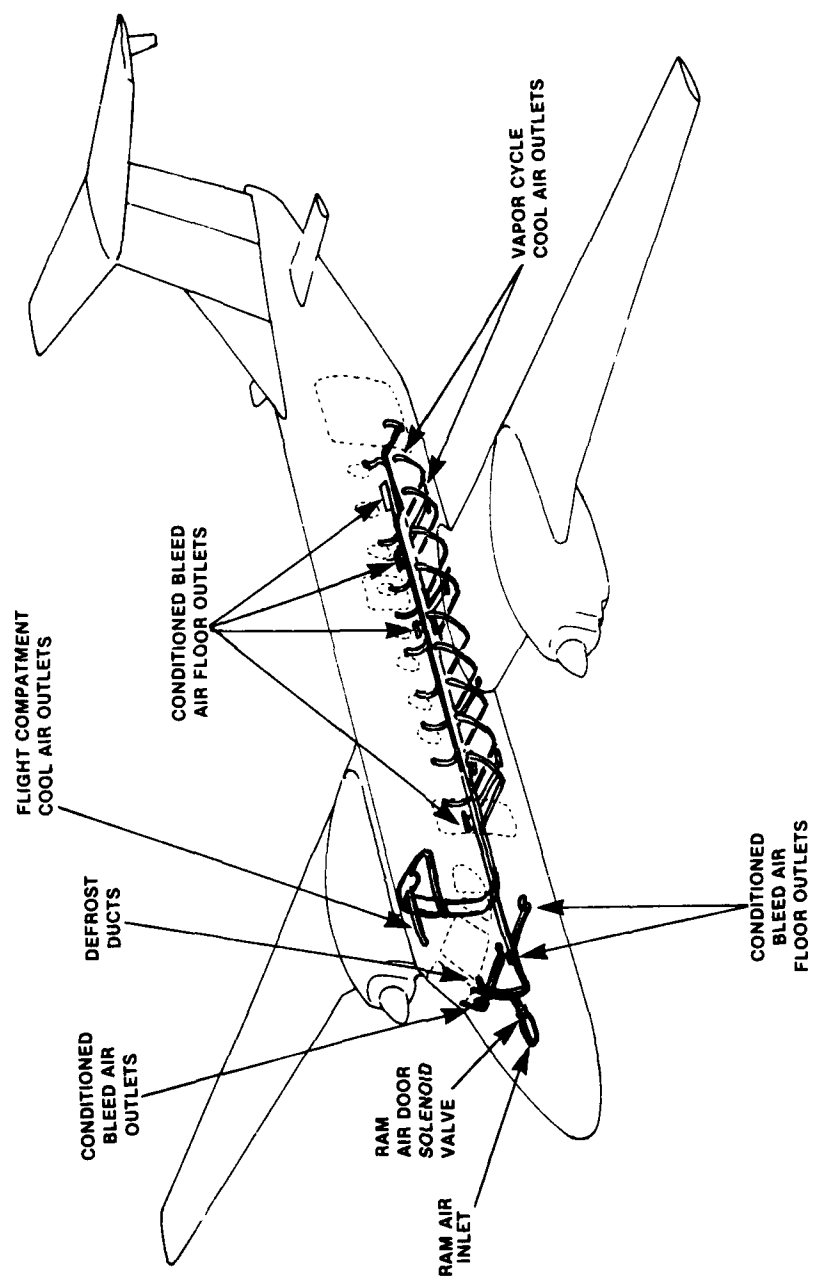


FIGURE 36. BEECH 1900 AIRLINER VENTILATION

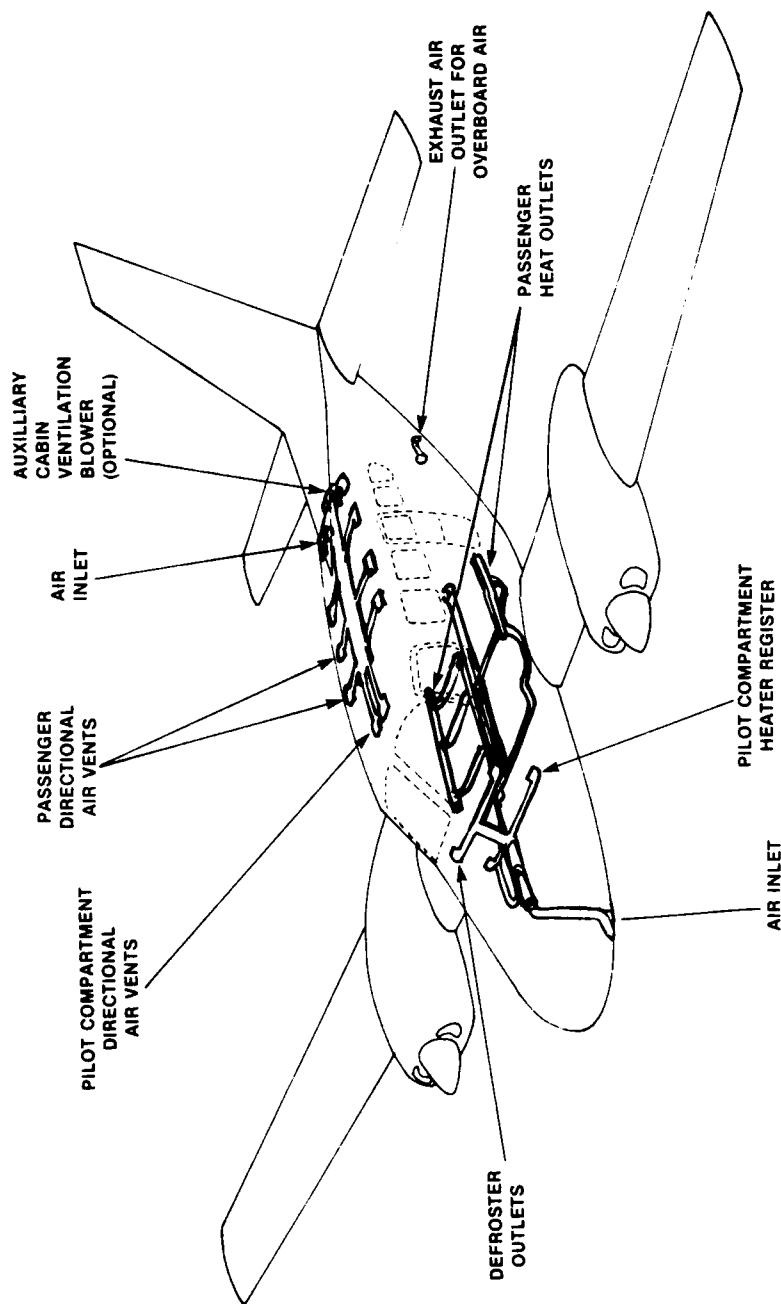
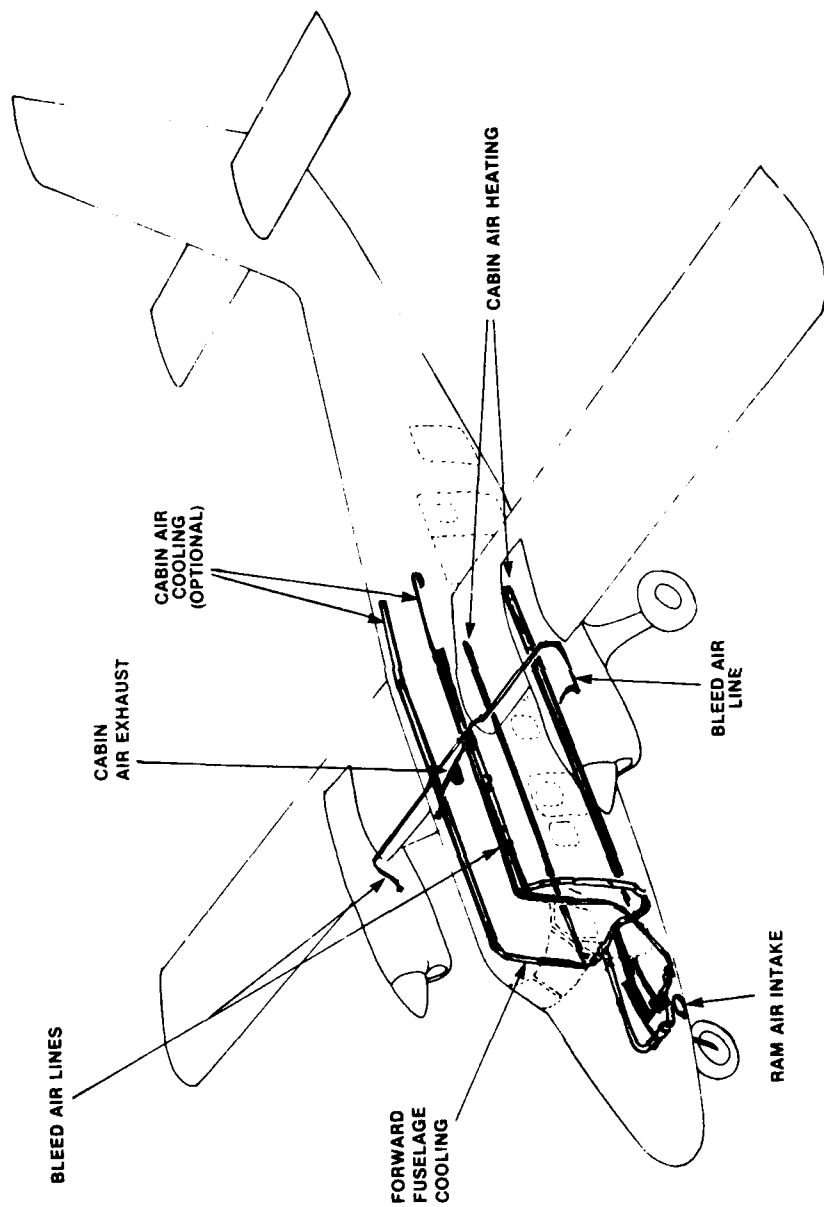


FIGURE 37. CESSNA 402 VENTILATION



**FIGURE 38. TWIN OTTER SERIES 300  
VENTILATION SYSTEM**



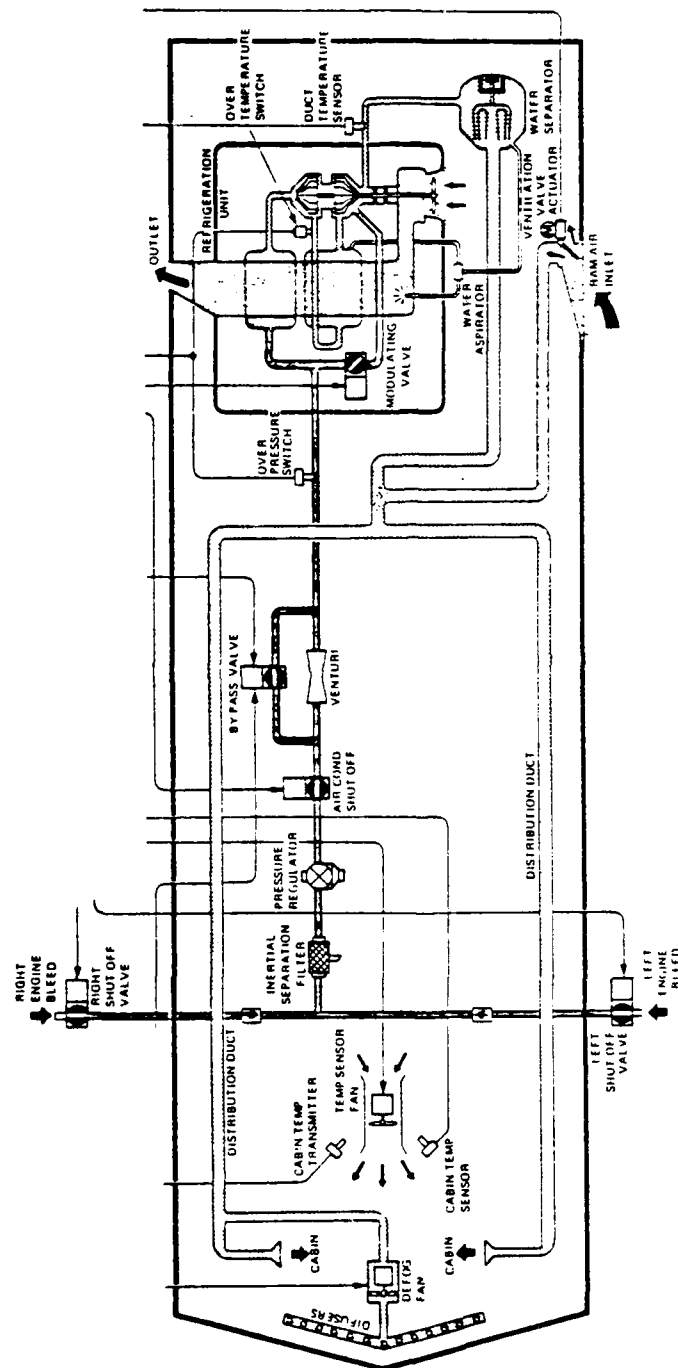
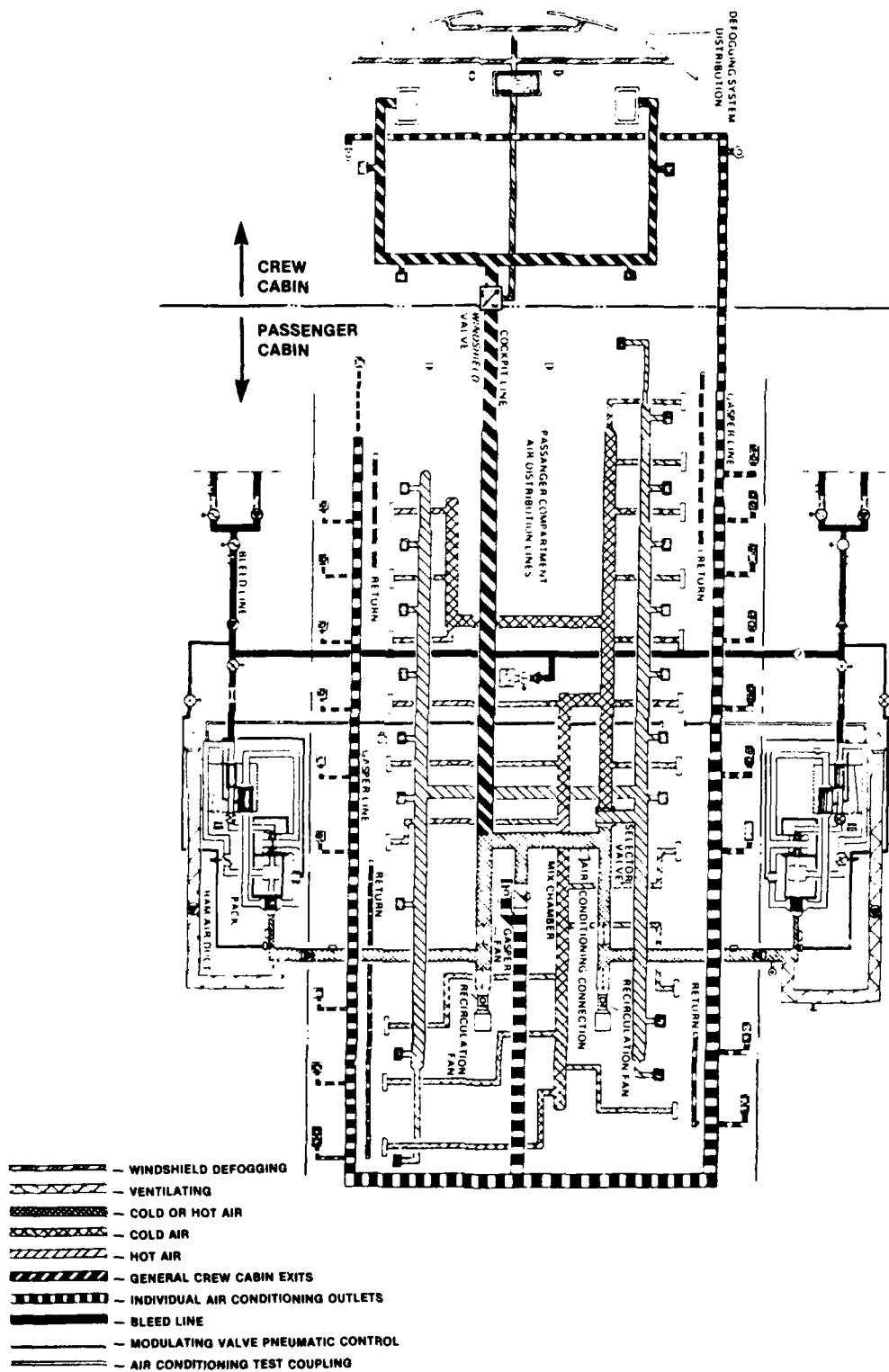


FIGURE 39. EMBRAER BANDEIRANTE VENTILATION



**FIGURE 40. EMBRAER BRASILIA VENTILATION SYSTEM**

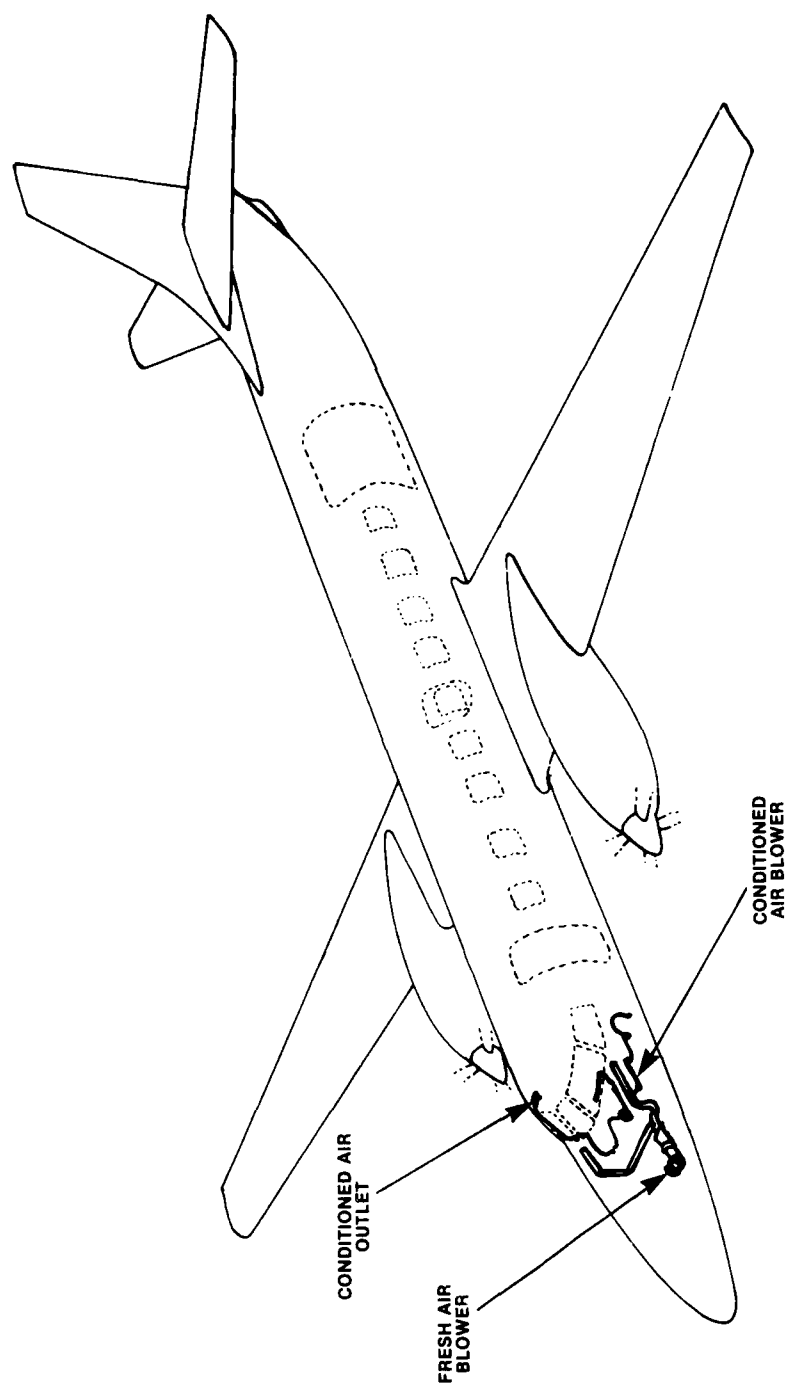


FIGURE 41. FAIRCHILD METRO III VENTILATION SYSTEM

1. HEATER INSTALLATION
2. HEAT-FRESH AIR OUTLET
3. DEFROSTER OUTLET
4. LEVER, COCKPIT AIRFLOW
5. LEVER, CABIN AIRFLOW
6. LEVER, DEFROSTER
7. LEVER, TEMPERATURE CONTROL
8. HEAT-FRESH AIR CONTROL BOX
9. FRESH AIR OUTLET, COCKPIT
10. HEAT-FRESH AIR OUTLET
11. CONTROL, FRESH AIR, RIGHT
12. CONTROL, FRESH AIR, LEFT
13. FRESH AIR OUTLET, CABIN
14. SCOOP, FRESH AIR
15. VENT OUTLET, CABIN
16. SCOOP, CABIN EXHAUST

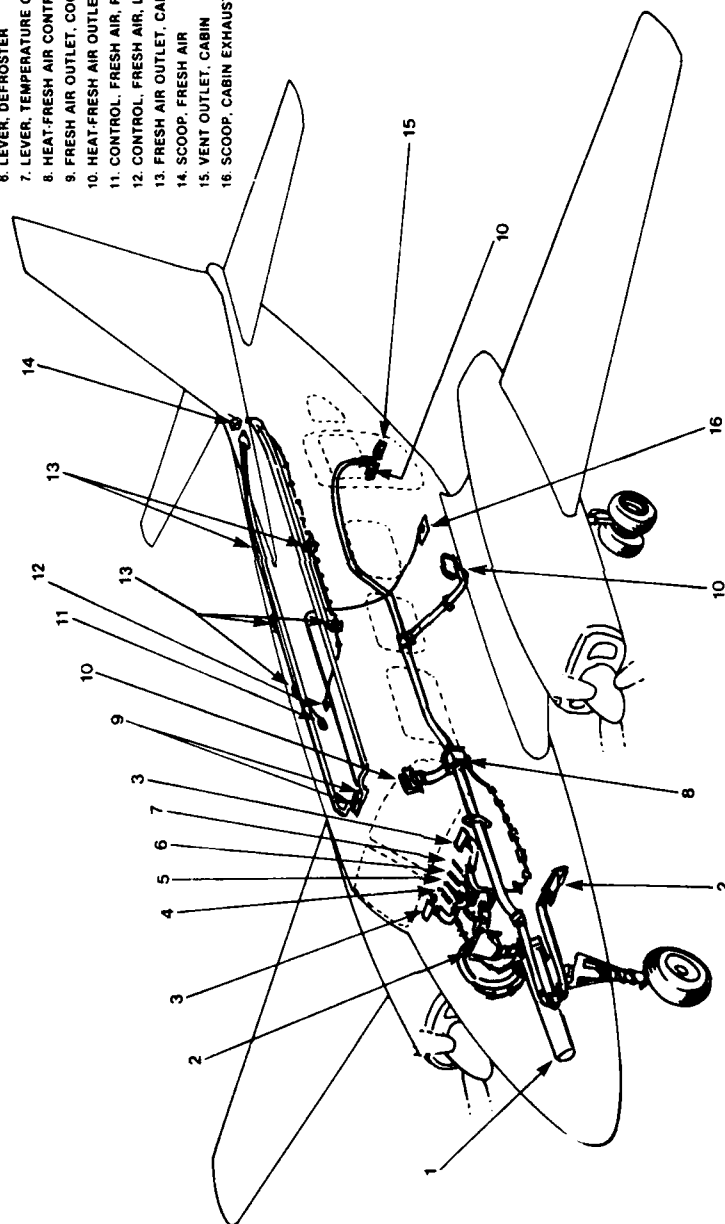


FIGURE 42. PIPER NAVAJO VENTILATION SYSTEM

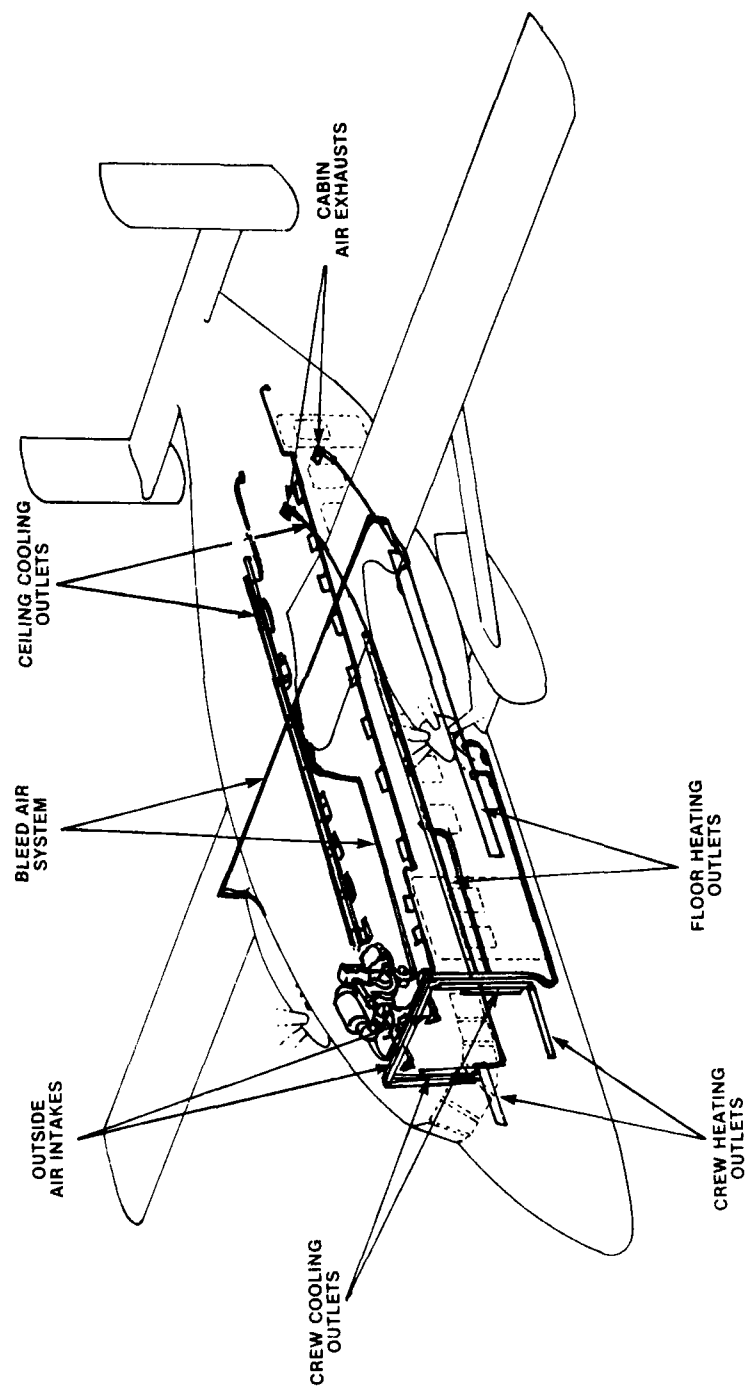


FIGURE 43. SHORTS 3-30 VENTILATION SYSTEM

## SUMMARY

The ten commuter aircraft selected for this study represent not only those aircraft most common in the commuter fleet, but also are representative of those most commonly being delivered to operators. The ten commuter aircraft in this study represent the majority of the current regional airline fleet of aircraft carrying thirty or fewer passengers, and, due to their numbers in service (880 out of 1100 commuter class aircraft), will be representative of the population for several more years.

The aircraft in this study illustrate trends in the commuter aircraft industry. The Cessna 402 and Piper Navajo originated as general aviation aircraft designed some years ago. They are relatively small, piston powered and simple in both design and materials applications. In the case of the Navajo, a turbine engine version has recently been placed on the market as a means of keeping the airframe saleable. The piston powered Navajo is not required to be equipped with engine fire detection and suppression capability while the turbine powered version is.

Of the other and larger eight aircraft, the deHavilland Twin Otter came into service in the late 1960s. It is also a very simple aircraft with, as an example, no cabin insulation. It is larger than newer aircraft of similar capacity, a characteristic derived from its development as an aircraft able to serve as the means of transportation and supply for remote, undeveloped areas. Both the Twin Otter and its contemporary, the Beech 99, are at the end of their delivery periods. Each is a derivative of older aircraft which were adapted to commuter service. Relatively new thermoplastics have been applied in each of these two aircraft, on a limited basis. The Embraer Bandeirante, though of new design, is not being delivered currently due to cost and market desire for larger aircraft.

In the other six aircraft, application of more modern materials is a major characteristic of the designs of the aircraft. The Fairchild Metro III makes some use of plywood as a core material to certain dividers, however, the predominant trend is to newer materials. The Shorts 330 is a large aircraft that features an interior purposefully appearing like that of airline aircraft operated by Part 121 commercial carriers. The Shorts 330, the Embraer Brasilia, the Metro III and the Beech 1900 each feature large, rear located, separate baggage compartments, leaving the cabin for seating. Only in the Shorts 330 and the Brasilia are there overhead storage bins installed.

Of the ten aircraft, only the Shorts 330 has a large interior that allows standing headroom in its large interior volume. The other aircraft, are much more compact, with interior storage limited to bins at the entry end of the aircraft.

Weight saving and durability seem to be keys to design success, possibly affecting the selection of various new thermoplastics and composite materials for the interiors. Each was originally delivered with polyurethane cushions; currently operators and manufacturers are involved in covering these cushions with fire blocking materials to upgrade fire safety.

The two piston powered aircraft use gasoline fired heaters without fire detection or fire suppression capability to provide cabin heat and ram air flow to provide outside air for cabin and cockpit cooling. The remainder of the aircraft are turbine powered, turboprop aircraft that use engine bleed air for heating and cooling of the interior air. The Beech 99, Cessna 402, deHavilland Twin Otter, Embraer Bandeirante, Piper Navajo and Shorts 330 are unpressurized aircraft while the BAe Jetstream 3100, Beech 1900, Embraer Brasilia and Fairchild Metro III are of pressurized design. The four pressurized aircraft are of newer design. The unpressurized aircraft have oxygen available for the pilots and passengers, often in portable storage form. The pressurized aircraft feature cabin oxygen for the passengers. Each of these aircraft reflects their operating environment of short, low altitude flight legs, not requiring design of oxygen systems characteristic of large commercial aircraft. In some of the aircraft, the fixed oxygen system is an option picked only by operators faced with the need for sustained high altitude operations, such as in mountainous areas. In these aircraft, oxygen is meant for emergency use of the crew and individual passengers with a temporary need.

The overall trend in the design of commuter airliners, as seen in this sample, is that of increasing sophistication in application of materials, in the newer aircraft, similar to that found in large commercial aircraft. With the exception of the deHavilland Twin Otter and the Shorts 330, these aircraft are small and offer relatively high performance.

# APPENDIX

## STANDARD DISTRIBUTION

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Aviation House  
129 Kingsway  
London WC2B 6NN England

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Embassy of Australia (1)  
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Berkely, CA 94720

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ATTN: NASA Rep.  
P.O. Box 8757 BWI Airport  
Baltimore, MD 21240

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AEA-61 (3)		ADL-1 (1)
ADL-32 North (1)	APM-1 (1)	ALG-300 (1)
AES-3 (1)	APA-300 (1)	ACT-5 (1)
ANM-60 (2)	AGL-60 (2)	AWS-100 (1)



ACT-300 Distribution

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Washington, DC 20591

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DOT/FAA National Headquarters  
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